Road and Transportation Research Association

FGSV

Guidelines for the Design of Motorways

R 1

RAA

Edition 2008
Translation 2011

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Working Group Highway Design

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English Version of Richtlinien für die Anlage von Autobahnen

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Working Group Highway Design
Committee Motorways
Task Group Urban Motorways

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Preliminary remarks

These Guidelines for the Design of Motorways (RAA), edition 2008, were made in both Task Groups "Motorways" and "Urban Motorways" (belonging to the Committee "Motorways", chairman until 2008: Dir. und Prof. Dipl.-Ing. Michael Rohloff, Bergisch Gladbach, followed by Prof. Dr.-Ing. Andreas Bark, Gießen).

The following people were members of the editorial team for these guidelines: Dr.-Ing. Marco Irzik, Bergisch Gladbach, RDir´in Dr.-Ing. Kerstin Lemke, Bergisch Gladbach, Univ.-Prof. Dr.-Ing. Christian Lippold, Dresden, OBR Dipl.-Ing. Lutz Nink, Mainz, Dir. und Prof. Dipl.-Ing. Michael Rohloff, Bergisch Gladbach and Univ.-Prof. Dr.-Ing. Wolfgang Wirth, Neubiberg. Frequent inquiries from foreign experts let the desire arise to make an English-language version of the Guidelines available to the international professional world. The following persons contributed to this English version: Mrs. Aingeal Flanagan, Cologne (translation), Univ.-Prof. Dr.-Ing. Werner Brilon, Karlsruhe (review) and Prof. Rod Troutbeck, Queensland, Australia (review).

The Guidelines for the Design of Motorways (RAA), edition 2008, replace the parts of the following regulations relating to motorways and urban motorways (category groups AS 0 to AS II in accordance with RIN):

- Guidelines for the Design of Rural Roads (RAL): Junctions and Interchanges (RAL-K), Section 2: Grade-separated intersections (RAL-K-2), 1976 edition (FGSV 290/5)
- Current References on the Design of Grade-separated Intersections outside Built-up Areas (supplements to RAL-K-2) (AH-RAL-K-2), 1993 edition (FGSV 290/6)
- Design References for Grade-separated Intersections on Roads Belonging to Category Group B (supplements to RAL-K-2) (RAS-K-2-B), 1995 edition (FGSV 290/7)
- Guidelines for the Design of Highways (RAS): Cross-sections (RAS-Q), 1996 edition (FGSV 295)
- Guidelines for the Design of Highways (RAS): Alignment (RAS-L), 1995 edition (FGSV 296)

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1 Introduction

1.1 Content

The Guidelines for the Design of Motorways *(Richtlinien für die Anlage von Autobahnen,* RAA[1]) are concerned with motorway design. As defined by the RAA, a motorway is a dual-carriageway, multi-lane, fully grade-separated road with no access to adjacent land. The term ‘motorway’ also covers motorway-like roads and urban motorways. These regulations apply to such roads regardless of signing in accordance with the German Road Traffic Regulations *(Straßenverkehrs-Ordnung,* StVO) and the road’s dedication in accordance with road law.

Essentially, these regulations refer to federal motorways signposted using the symbol Z 330 for motorways stipulated by the StVO and featuring blue signing. Motorways can, however, also be signposted using the symbol Z 331 for trunk roads stipulated by the StVO and featuring blue or yellow signing. In terms of their dedication according to road law, motorways can also be federal highways, Land highways (i.e. federal state highways), district highways, or municipal highways.

Unless a specific differentiation is made in the body of this text, all of these roads are referred to as ‘motorways’ in the RAA.

The RAA contain planning principles (methods, design elements, and equipment characteristics) for the construction of new motorways and for the reconstruction and improvement of existing motorways (e.g. the widening of the cross-section, re-alignment, redesign of junctions).

[1] Acronyms used in this document are based on the German nomenclature.

1.2 Purpose

The RAA form the basis for the design of reliable serviceable motorways that meet functional requirements. The design principles contained in the RAA are based on the function of the network, which is indicated by the road category as defined in the Guidelines for Integrated Network Design *(Richtlinien für integrierte Netzgestaltung,* RIN). The aim is to establish uniform standards for motorways of the same type.

The RAA do not offer ready-made solutions for all design tasks. It allows for discretionary authority to be exercised, which should be used when considering the various requirements and objectives of the project.

In individual cases, it is possible to deviate from the limiting values. However, in such cases, the reasons for doing so must be documented.

1.3 Scope

The RAA apply to motorway categories AS 0 to AS II as defined in the RIN (Table 1).

Dual carriageway sections of roads that otherwise only have one carriageway and belong to category LS as defined in the RIN are treated in accordance with the Guidelines for the Design of Rural Roads *(Richtlinien für die Anlage von Landstraßen,* RAL).

The guidelines can be applied as appropriate in the following planning stages: preliminary planning, design planning, approval planning, and planning the execution of works.

Table 1: Road categories as defined by RIN and the scope of the RAA

Category group / **Link function level**		Motorways	Rural roads	Trunk roads in non built-up areas	Trunk roads in built-up areas	Local roads
		AS	**LS**	**VS**	**HS**	**ES**
continental	**0**	**AS 0**		–	–	–
sub-continental	**I**	**AS I**	LS I		–	–
inter-regional	**II**	**AS II**	LS II	VS II		–
regional	**III**	–	LS III	VS III	HS III	
sub-regional	**IV**	–	LS IV	–	HS IV	ES IV
local	**V**	–	LS V	–	–	ES V

Legende:

AS I	Designation of the category as it occurs
(grey)	problematic
–	does not occur or is not justifiable

2 Objectives and measures

2.1 General remarks

Motorways are high-capacity roads. They are operated exclusively for fast motor traffic and are designed to function with both a high level of road safety and high-quality traffic flow.

Motorways should not only comply with the necessary design standards, but also protect the surrounding environment and use as few resources as possible. The cost of building, maintaining, and operating motorways should be as low as possible.

Planning motorways is, therefore, a question of meeting a variety of demands. Motorways should

- provide a direct link between traffic sources and destinations;
- guarantee the target travel speeds determined by spatial and land use planning requirements;
- provide sufficient capacity to cope with forecast traffic volumes in order to avoid oversaturation and congestion;
- have homogenous road characteristics;
- where possible, avoid sealing with a pavement or the crossing of environmentally sensitive areas, or reduce such crossings to a minimum and take protective measures to safeguard environmentally valuable areas in the vicinity of the motorway;
- support land use and spatial development objectives;
- adapt the alignment to suit both the terrain they cross and local constraints;
- not appear monotonous to the driver, but instead be diverse in appearance to keep drivers alert;
- maintain the necessary distance from environmentally sensitive areas or be combined with other traffic routes;
- be aligned in such a way that nuisance caused by road noise and pollutant emissions are avoided as much as possible.

The many and varied impacts of motorways mean that a variety of considerations must be taken into account, i.e. not only objectives such as a safe and functional traffic flow, but also the conservation of nature, the preservation of limited resources, and the impact of motorways on populated areas and the appearance of the region.

When evaluating competing demands during the various planning stages, discussions are generally based on a number of different draft designs. By evaluating the objectives or criteria, i.e.

- road safety,
- traffic flow quality,
- spatial and land use planning, town planning, environment, and agricultural structures, as well as
- costs,

the most appropriate design can be drafted (see Sections 2.2 to 2.5). The inclusion of cost-benefit analyses makes it possible to develop solutions that achieve benefits for society as a whole at the lowest possible expense.

It is sensible to conduct such cost-benefit analyses, which are sometimes stipulated by the budget regulations of the Federal Government and the Länder (Germany's federal states), during the alignment planning and design planning stages in particular in order to determine the cost-effectiveness of a project or its variants. However, cost-benefit analyses may also be necessary for individual draft solutions at later planning stages.

The validity of cost-benefit analyses should be checked for the entire project at regular intervals if the planning process extends over a long period.

The procedures in place compare the annualized costs of a road investment project (a new construction) with the monetized and annualized traffic flows. In the case of an investment in road improvement and maintenance, the depreciation of the additional structural components required to complete the project are added to the accrued construction costs. The corresponding operational costs for the sections in question are included in the analysis of all investment types.

Motorways should be designed in such a way that the ratio of benefits to costs is as high as possible.

It is not possible to provide a definitive monetized value for a range of road impacts, including damage to the environment, nature, or landscape. In addition to the cost-benefit analyses, such impacts must be taken into consideration and the discussions documented. This is done separately as part of one of the following objectives, thereby ensuring that they are weighed up with all the other considerations.

Depending on the scope and impacts of a project, special reports, such as

- traffic surveys,
- road safety audits and road safety statements,
- cost-benefit analyses,
- environmental impact assessments,
- FFH (flora fauna habitat) impact assessments,
- reports on the protection of species/biodiversity,
- reports on agricultural structures,
- town planning reports,
- emission surveys, and
- geological and/or water management surveys

are necessary in order to underpin the overall objectives and to consider all factors.

Traffic-law related specifications must be agreed with the traffic authorities as part of the evaluation process.

2.2 Road safety

Motorways have to cope with high traffic volumes and allow vehicles to travel at high speeds. For this reason, safety is of particular importance. Design and operation characteristics are used to influence road user behaviour and, consequently, road safety.

Motorways should be designed and equipped in such a way that

- the characteristics of the road are as homogenous as possible over large sections;
- road users can adapt their speed in time to suit the course of the road and the traffic situation;
- junctions can be identified well in advance;
- the occupants of errant vehicles and areas/habitats alongside the road that need protection are protected against the serious consequences of road accidents;
- road users can make emergency stops alongside the carriageway; and
- road users can call for assistance in emergencies using roadside emergency telephones.

Table 2 contains a selection of important objectives and possible influencing variables.

Road safety is enhanced when

- generous design elements (not minimum elements) are used;
- the sequence of elements in the horizontal alignment is balanced;
- horizontal and vertical alignments are co-ordinated and adapted to suit one another;
- road users can see sufficiently in the distance along the section of road on which they are travelling;
- the cross-section (in particular at construction works) is sufficiently wide and has a hard shoulder;
- signposts are erected sufficiently far ahead and are not ambiguous;
- surface water is drained away as directly as possible and areas with poor drainage are avoided;
- lateral obstacles are avoided or
- action is taken to provide protection against dangerous obstacles (e.g. vehicle restraint systems or safety barriers and crash cushions);
- accidents involving wild animals are minimized by the erection of suitable fences, animal crossings in the form of bridges or underpasses, and/or by not planting plants that attract animals;
- markings and traffic guidance equipment are applied and implemented properly.

The Recommendations for Road Safety Audits *(Empfehlungen für das Sicherheitsaudit von Straßen,* ESAS) contain other possible ways of improving road safety. In addition, these recommendations require a road safety audit to be conducted before each planning stage is completed.

Table 2: Road safety

Objectives	Possible influencing variables
Safe vehicle tracking	– Radii – Three-dimensional alignment – Sight distance – Crossfall and incline – Drainage
Safe travel alongside or behind other vehicles	– Longitudinal gradients – Climbing lanes – Sufficient lane width at roadworks – Hard shoulders – Traffic control systems
Junctions with a low number of conflict points	– Separation of decision points and conflict points – Generous design elements in both the horizontal and vertical plane – Sufficient weaving distances or the avoidance of weaving areas – Sufficient sight distances with regard to oncoming traffic – Sufficient distances between consecutive junctions for directional signing – Adequate sight distance for merging
Safe central reserves and roadside areas	– Density of obstacles alongside the carriageway – Distance between the obstacle and the edge of the carriageway – Quality of the vehicle restraint equipment or safety barrier – Hard shoulders (marginal strips) – Deceleration lanes and coasting areas at the exits – Protected emergency telephones
Safe maintenance procedures	– Width of the hard shoulders – Design of the maintenance access roads – Selection of vehicle restraint equipment

2.3 Traffic flow quality

Motorways should ensure high-quality traffic flow and appropriate travel speeds.

Table 3 lists some possible influencing variables.

The desired traffic flow quality is calculated on the basis of the specified target mean travel speed for the relevant road category in accordance with the Guidelines for Integrated Network Design (RIN). Traffic flow quality is enhanced when

- the alignment is generous;
- the dimensions of the cross-section are sufficient, even for peak times (hour of measurement) in the forecast period, and drivers can travel at acceptable speeds for the planned environment;
- there is a sufficient number of lanes on ascending gradients (climbing lanes);
- the number of junctions is restricted to the absolute minimum required;
- sufficient room is available for road maintenance and road operational services to ensure that they do not hamper traffic flow unnecessarily;
- the usual number of lanes remains in use during roadworks and the inspection of structures.

The quality of the traffic flow is inspected on the basis of the German Highway Capacity Manual *(Handbuch für die Bemessung von Straßenverkehrsanlagen,* HBS).

2.4 Spatial planning, town planning, nature, and the environment

Roads ensure that people can get from one place or town to the next (place of work, education, supplies, and leisure activities). They are an integral part of the system of 'key locations'. The functional structure of traffic networks allows for a task-related combination and distribution of traffic flows.

In this context, motorways provide the basic framework for long-distance traffic and are, therefore, an important spatial and land use planning tool. Because motorways are spatially significant major projects of regional significance, the long-term spatial development objectives outlined in the Spatial Development Act *(Raumordnungsgesetz,* ROG) must be taken into consideration when planning a motorway. The main objectives are listed in Table 4; supplementary information on these objectives can be found in a number of sources, including the RIN.

Motorways on the outskirts of or within built-up areas have a significant effect on the image of the city. For residents, they constitute a major element in their living environment. It is generally from the road that drivers get a first impression of the urban environment. Because of their importance as a transport link and the resulting high quality of the traffic flow when compared with the subsidiary urban road network, urban motorways – and in particular their junctions – tend to make locations particularly attractive for business and industry.

For this reason, the integration of urban motorways in a manner that is compatible with town planning objectives is of particular importance. This importance is reflected in the fact that a town planning report (e.g. in accordance with the Recommendations on Designing Roads in Built-Up Areas *(Empfehlungen zur Straßenraumgestaltung innerhalb bebauter Gebiete,* ESG) is generally drawn up at the preliminary planning stage. Important aspects of this report include, among others, the layout of the road (horizontal and vertical alignment, superstructures, substructures) and the layout of the roadside area (proximity to buildings, protection provided by active noise barriers).

Table 5 contains a selection of corresponding objectives and possible influencing variables. Moreover, Appendix 1 contains pointers for cross-section design variants that are suitable for the surrounding environment.

Motorways have an effect on their immediate and broader environment. In view of their relatively large design elements and the fact that they take up a lot of space, motorways generally impact on nature and the landscape in terms of their design, construction, and operation.

They must be designed in such a way as to have the least possible impact on both the various subjects of protection identified by the Environmental Impact Assessment Act *(Gesetz über die Umweltverträglichkeitsprüfung,* UVPG) and their interaction with one another.

On the basis of the applicable specialty laws, there are comprehensive evaluation standards for determining, describing, and evaluating the effects of the project on environmental and conservation-related concerns; these must be included in the planning process as appropriate.

Conservation regulations are of particular importance in this regard. Interference with nature and the landscape must be avoided or reduced as much as possible, by, among other things, the planned alignment of the road. For example, in accordance with the Code of Practice for Environmental Conservation and Landscape Management in the Construction of Federal Trunk Roads *(Hinweise zur Berücksichtigung des Naturschutzes und der Landschaftspflege beim Bundesfernstraßenbau,* HNL-S), the effect on nature and the landscape is reduced by

- making a minor change to the alignment of the route,
- adapting the design elements in the horizontal and vertical alignment, the design of cross-section and junctions, or

structural measures (e.g. supporting structures, amphibian tunnels, bridge design).

For this reason, motorways should, where possible,

- take up as little space as possible in terms of their structure and layout;
- change the natural environment as little as possible;
- keep an appropriate distance from anything that would be negatively affected by the motorway;
- minimize the number of people affected by them.

Agreement must be reached with the spatial planning and nature conservation authorities during the planning stage.

In the case of motorways in built-up areas, it is important to take account of the impact of the motorway on land uses that are sensitive to emissions and the potentially negative impact on structures that are characteristic of the town or valuable in terms of town planning objectives. The shortage of available space often leads to pronounced conflicts between the use of motorway and other modes of transport and town planning concerns. For this reason, Appendix 1 shows a number of ways of integrating urban motorways and developing the urban environment.

The Guidelines for Construction Measures on Roads in Water Protection Areas *(Richtlinien für bautechnische Maßnahmen an Straßen in Wasserschutzgebieten,* RiStWag) contain the requirements for drainage methods on motorways in water protection areas.

Table 6 contains a selection of main objectives and possible influencing variables.

Table 3: Traffic flow quality

Objectives	Possible influencing variables
Appropriate traffic flow quality	– Number of lanes – Hard shoulders (marginal strips) – Longitudinal gradientsAdditional lanes – Horizontal alignment – Traffic guidance around construction works – Cross-section/design of slip roads – Link roads

Table 4: Spatial planning

Objectives	Possible influencing variables
Spatial development, link function, and connectivity Functional structure and quality of supply Relief function Regulation and control function	– Appropriate definition of the road category and link function level-Number, position, alignment, and integration of network elements – Position in relation to main settlement areas and business/industrial locations – Position and organization of link points with the subsidiary network

Table 5: Town planning

Objectives	Possible influencing variables
Development and link function Relief function Protection against noise and visual impact Reduction of the barrier effect	– Correct definition of the road category and the link function level – Location for construction – Spatial location – Horizontal and vertical alignment (depressed road, road at grade, elevated road) – Width – Junctions that take up a small amount of space horizontally and vertically – Positioning and design of emission control structures – engineering measures (tunnels, galleries, enclosures, superstructures, substructures) – Flyovers and underpasses for crossing traffic

2.5 Costs

When calculating the costs to the construction authority, investment costs including costs for the necessary compensatory and replacement measures, land acquisition, and the recurrent expenditure for road maintenance must be taken into account. The construction authority's total investment should be as low as possible.

Table 7 contains a list of objectives and potential influencing variables.

Because of their design standards, the construction costs for motorways are high. Nevertheless, costs can be reduced by

- keeping the route as direct as possible;
- ensuring that that route is largely adapted to suit the terrain;
- avoiding areas with soil that either has poor bearing capacity or is otherwise unsuitable;
- keeping the length of civil engineering structures as short as possible;
- ensuring that the intersection angle of bridges is almost a right angle;
- choosing areas where open drainage into the landscape is possible;
- avoiding active measures to control emissions;
- avoiding sensitive areas that require high compensatory measures;
- designing motorways in an operation- and maintenance-friendly manner, e.g. by keeping the number of obstacles for operation services to a minimum;
- choosing attachments and equipment with a stable, wear-resistant design.

When widening a road from four to six lanes, the issue of whether to widen the road on one side only or on both sides should also be examined. Widening the road on one side only is preferable in the case of roads that have narrow cross-sections and no hard shoulders. In terms of construction technology and traffic engineering requirements, this option will result in excessively wide medians or an excessively wide verge. If, on the other hand, the original cross-section of the road is wide, widening the road on both sides generally allows for temporary four-lane traffic and sufficient space for the construction works during the works period (see Appendix 2).

Table 6: Nature and the environment

Objectives	Possible influencing variables
Little or no use of sensitive areas	– Horizontal alignment – Gradient harmonization – Landscaping embankments – Number of lanes – Hard shoulders – Junction systems/elements – Control and maintenance facilities – Protective measures
Little or no negative impacts (due to pavement sealing, superstructures, dissection of areas) on important area functions and considering negative influences on – habitats – the migration of animal species – the interlinking of habitats (connecting biotopes) – biodiversity – water resources – neighbouring low-traffic areas	– Horizontal alignment – Concentration of roads and other transport routes – Bridges/underpasses, culverts
Low emissions and low emission load	– Horizontal alignment – Longitudinal gradients – Height of embankment and depth of cut – Drainage – Emission control structures on the road
Good microclimate	– Height of embankment and depth of cut – Emission control structures on the road – Civil engineering structures
Road design that respects the landscape	– Adaptation of the alignment of the road in accordance with the topography – Planting for beautification – Planting or other ways of designing emission control structures

Table 7: Costs

Objectives	Possible influencing variables
Low capital expenditure	– Duration of planning – Planning consistency or effectiveness – Avoidance of changes to the plan – Cross-section – Alignment – Adaptation of the route to suit the terrain – Civil engineering structures – Junction systems – Control and maintenance facilities – Equipment – Protective devices – Emission control structures on the road
Low maintenance and operation expenditure	– Facilities for road operation and maintenance services – Technical aspects and design of structural equipment – Possible work areas and access for inspecting and repairing structures

3 The fundamental principles of planning and design

3.1 The various planning and design stages

Planning the construction of new motorways and the reconstruction and improvement of existing motorways is an iterative process that involves a number of different planning and design stages.

The RAA only provide information on the basic planning and design stages. These stages must be transferred to the actual project and its specific conditions. The iterative design process often results in changes, e.g. as a result of the conditions imposed by the approval procedure or the assessment procedure.

Before the road is actually designed, the plan is justified on the basis of requirement plans outlined in corresponding laws concerning the development of roads at both federal and *Land* level. At federal level, the German parliament approves the Requirement Plan for Federal Trunk Roads (Appendix to the Development of the Federal Trunk Road Network Act, *Fernstraßenausbaugesetz,* FStrAbG) on the basis of the Federal Traffic Infrastructure Plan presented by the Federal Government.

In the case of urban motorways constructed by municipalities, the procedure, which involves transport development plans, is similar to the one at federal level.

The RAA do not contain information on the planning of requirements.

The designation of the various planning stages that follow on from one another are based on the definitions in the Ordinance concerning Remuneration for Architects and Engineers (*Honorarordnung für Architekten und Ingenieure,* HOAI) and the Manual Concerning Contracts Governing the Services Provided by Freelance Engineers and Landscape Architects in the Construction of Roads and Bridges (*Handbuch für die Vergabe und Ausführung von freiberuflichen Leistungen im Straßen- und Brückenbau*, HVA F-StB). In some road administrations and in other guidelines, different terms are used for the same planning stages. The planning stages are followed by corresponding approval procedures (see Table 8).

Since the **preliminary planning stage** is the stage of conceptual planning, its primary function is to identify the alignment of the new motorway. This stage is generally completed as part of the spatial planning procedure and ends with the determination of the alignment. During the spatial planning procedure, assessments are conducted to determine whether the motorway complies with spatial planning requirements and whether, in this regard, it has been co-ordinated with other spatially significant plans or measures (territorial impact assessment with environmental impact assessment). Depending on the jurisdiction in question, the process of evaluating all considerations relating to a project uses either the spatial planning or the alignment determination procedure.

Table 8: Stages of motorway planning and design as well as the relevant service phases as defined by the HOAI

Planning and design stages	Document	Procedure	Service phases (Lph) in accordance with HOAI and HVA F-StB
Planning the requirements	Federal Traffic Infrastructure Plan/Requirement Plan (federal trunk roads) General Traffic Plan, Traffic Development Plan, and comparable plans	Federal traffic infrastructure planning Development of the Federal Trunk Road Network Act (FStrAbG) with Requirement Plan	
Preliminary planning stage	Planning/designing the alignment	Spatial planning procedure Determination of the alignment	Basic evaluation (§ 55 Lph 1) Preliminary planning (§ 55 Lph 2)
Design planning stage	Preliminary design in accordance with the RE/ approval design	Approval by the authority responsible for approval, marked by the Federal Ministry of Transport, Building and Urban Development (BMVBS) as having been seen (depending on the cost of the construction project)	Design planning stage Approval design (§ 55 Lph 3)
Approval planning stage	Design submitted for official (plan) approval	Official plan approval Adoption of the plan	Approval planning (§ 55 Lph 4)
Final planning stage	Final design/construction design	Technical approval	Final planning (§ 55 Lph 5)

The preliminary planning stage begins – generally on the basis of the Requirement Plan – within the established analysis limits of the planning area, which should include all variants that are appropriate from a traffic point of view and must be broad enough to ensure that all significant impacts on the surrounding environment of the future road can be determined.

An environmental impact assessment (EIA) is generally necessary for the integrated identification of areas with a low number of conflict points and for the assessment of the project's environmental impact, which is prescribed by law. It must be conducted as part of the preliminary planning stage and as a separate specialty planning document.

In accordance with the Information Sheet concerning Environmental Impact Assessments in Road Planning (*Merkblatt zur Umweltvertraglichkeitsstudie in der Straßenplanung*, M UVS), the effects of a project on the environment are determined, described, and evaluated for each area and road variant. The EIA generally contains the following sections:

– spatial analysis
– expected impacts
– comparison of variants.

The spatial analysis includes the identification, description, and evaluation of the protection and also includes the identification of sub-areas with a low number of conflict points or areas of with significant conflicts (see Section 2.4). Areas or corridors with relatively low numbers of conflict points and the cross-section and gradient solutions can be evaluated by superimposing the results for the protection on each other.

At this level, this stage also involves the inclusion of the NATURA 2000 map of eligible areas and consideration of European biodiversity regulations. The intensity of the assessment depends on the planning scale and the inherent problem(s) and these are important factors in the identification of suitable alignments that lead to sustainable solutions.

At the preliminary planning stage, the fundamental design and operation characteristics are selected in accordance with the design class EKA (see Section 3.2). These characteristics are then used to develop a variety of different horizontal and vertical alignments. Preferably, these alignment variants should cross the corridors with a relatively low number of conflict points.

Moreover, for motorways belonging to design class EKA 3, a variety of cross-section designs (Appendix 1) that meet the requirements of the environment in general and the detailed environment of the motorway should be investigated (see Section 3.2).

The number of junctions as well as their positions and basic forms must also be specified at this planning stage. The same applies to civil engineering structures and their fundamental dimensions.

Subsequently, all variants should be assessed in terms of their road safety characteristics on the basis of the ESAS.

After evaluating all concerns (see Section 2), a preferred variant is then generally selected and further developed in the subsequent planning stages.

The preliminary planning stage is also mandatory for the improvement and widening of existing motorways. In these cases, however, the assessment of variants generally relates to a narrow corridor already determined by the existing motorway. Deviations occur very rarely, and generally in cases where the immediate environment imposes particularly heavy restrictions.

At this stage, an assessment is also conducted in order to establish whether a fully unilateral widening or a symmetrical widening should be chosen when widening an existing motorway from four lanes to six (see Appendix 2).

The identification of the alignment is generally recorded on plans with a scale of 1 : 10,000. For the summary presentation of the assessed variants, a scale of 1 : 25,000 is also suitable.

For motorways being constructed by the Federal Government, the preliminary planning stage ends with the determination of the alignment.

At the **design planning stage,** the horizontal and vertical alignment of the preferred variant is further specified (from the preliminary design). The design class (see Section 3.2) determines the design standard (standard cross-section, alignment, junctions). In comparison with the preliminary planning stage, realignments are still possible within a limited corridor. For practical reasons, changes made at the start of the design planning stage are an interim step and are based on an optimization of the alignment and presented on plans on a scale of 1 : 5,000.

The preliminary design must take the specifications of the Federal Nature Conservation Act (*Bundesnaturschutz-Gesetz*, BNatSchG) or corresponding laws at *Land* level into consideration in terms of the regulation of impacts, biodiversity, and European territorial protection. To this end, the necessary reports (LBP, FFH impact assessment etc.) must be drafted.

The purpose of the preliminary design is to provide the basis for internal administrative and engineering assessment. It provides the cost framework stipulated by fiscal law and is the basis for the sums of money earmarked in the budget. It includes any necessary divisions of costs (e.g. at junctions). It also provides evidence of the land area required for the project.

Having drafted the geometric road design, evidence of the quality of the traffic flow must be provided on the basis of the HBS.

Moreover, after the design planning stage, a road safety audit must be conducted in accordance with ESAS and approved proposals for amendment must be included in the next phase.

The design plan is drafted in accordance with the Guidelines for the Drafting of Uniform Design Documents in Road Construction (*Richtlinien für die Gestaltung von einheitlichen Entwurfsunterlagen im Straßenbau*, RE). Supplementary detailed plans that are relevant for the assessment process may also be necessary. The plan documents are generally drafted on a scale of 1 : 1,000 or, in exceptional cases, on a scale of 1 : 2,000 or 1 : 5,000.

At the **approval planning stage,** the preliminary design is developed and enhanced (design submitted for approval). Here, the information is presented with adequate detail for an official decision. The approval planning stage must provide all parties involved in the official approval of the plan with information about the type and scope of impact. It forms the basis of the decision to grant official approval, for which all public and private concerns are evaluated against each other, and for the acquisition of land.

Regulations concerning any necessary restrictions regarding maximum permissible speeds are generally drafted by the responsible traffic authorities outside the official approval of the plan procedure.

The documents for the approval planning stage are drafted in accordance with the Guidelines for Official Plan Approval in Accordance with the Federal Trunk Road Act (*Richtlinien fur die Planfeststellung nach dem Bundesfernstraßengesetz*, PlafeR) and also contain, among other things, an index of engineering structures and a land acquisition index with a land acquisition plan. In comparison with the preliminary design in accordance with RE, these plan documents do not contain cost calculations to the detail required in the Instructions for Calculating Costs in Road Construction (*Anweisungen fur die Kostenberechnung im Straßenbau*, AKS) and do not contain a soil investigation report.

In the case of a motorway that is not being built by the Federal Government (see Section 1.1), the documents for the approval planning stage are drawn up in accordance with *Land* road laws and requirements.

The plan documents are generally drawn up on the same scale as those used for the preliminary design.

The documents for the **final planning stage** (final design, construction design) are drawn up on the basis of the officially approved plan, i.e. after the right to build has been granted. The conditions or regulations in the decision to grant official approval must be included in the plan.

The documents for the final planning stage must contain all necessary information and plans for the invitation to tender and the execution of construction works (e.g. setting out plan, cross-sections, pavement height plans). Other documents that must be drawn up in the final planning stage include signing and marking plans (traffic sign plans), co-ordinated control plans, an integrated construction procedure plan, as well as landscape management plans (References on the Implementation of Landscape Management Compensation Measures in the Construction of Trunk Roads, *Hinweise zur Umsetzung landschaftspflegerischer Kompensationsmaßnahmen beim Bundesfernstraßenbau*, RAS-LP 2) and, if necessary, other specialized plans.

A road safety audit must also be conducted in accordance with the ESAS for the final design.

The plan documents for the construction design are generally drawn up on a scale of 1 : 1,000 and 1 : 500 (and in exceptional cases, 1 : 250). These documents must be archived as they constitute the final, approved plans for the project and will be needed for future reference.

3.2 Road categories and design classes

In order to ensure the uniformity of motorways with equivalent network functions and traffic significance, motorways are divided up into motorway design classes (EKAs) and designed accordingly.

The variables that determine the design class are the road category, the position of the motorway in relation to built-up areas, and the motorway's jurisdiction (see Table 9). These variables take into consideration the significance of the motorway in terms of spatial planning and traffic and also claims originating in the surrounding environment.

In view of the fact that the traffic functions of a motorway sometimes overlap, it is not always possible to make a clear distinction. The specifications outlined in the RIN are decisive in this regard.

Motorways that belong to the categories AS 0 and AS I both inside and outside built-up areas (long-distance motorways) and motorways that belong to category AS II outside built-up areas (inter-regional motorways) are designed in accordance with EKA 1. In order to ensure that the significance of the link (link function level) is adequately taken into consideration, EKA 1 is divided up into EKA 1 A (AS 0 and I) and EKA 1 B (AS II). Graded design elements for alignment are allocated to each class (see Section 5). Unless expressly indicated otherwise in the text, the regulations outlined here apply to all EKA 1 motorways.

The motorway-like roads that belong to EKA 2 include all motorways that are not federal motorways and are not urban motorways. These motorways are used for short or medium-distance links and have lower requirements in terms of the travel speeds that can be reached on them. This explains why EKA 2 has lower limiting values for design elements, thereby allowing for a more flexible alignment than is the case with EKA 1.

For the most part, urban motorways cross built-up, urban areas. They are generally part of the urban trunk road network and, as a link between the urban road network and the higher-ranking inter-regional motorway network, can be integrated into the network of long-distance motorways or inter-regional motorways. They are almost always subject to restrictions imposed by the built-up surroundings and are designed in accordance with EKA 3.

The design class should not change. The only cases in which a change of design class is justified is where the position of a motorway, that belongs to the category AS II for EKA 2, changes to a built-up area. Such changes may only occur at motorway junctions.

3.3 Design classes and design features

The road category and the design class determine the features as well as the limiting values and guide values for the design and operation elements. This is why motorways and motorway-like roads have different road characteristics.

The design class directly determines

- standard cross-sections,
- limiting and guide values for design elements,
- basic forms of junctions and the distances between them, and
- where applicable, the application of a speed limit.

Table 10 outlines the fundamental allocation of design classes and design features. Table 26 (see Section 9) contains a comprehensive overview of the respective design elements.

Table 9: Design classes for roads belonging to category AS

Road category	AS 0/AS I		AS II		
Position in relation to built-up areas	outside or inside		outside or inside	outside	inside
Jurisdiction	Federal motorway	Non-federal motorway	Federal motorway	Non-federal motorway	All
Designation	Long-distance motorway	Motorway-like road	Inter-regional motorway	Motorway-like road	Urban motorway
Design class	EKA 1 A	EKA 2	EKA 1 B	EKA 2	EKA 3

Table 10: Design classes and design features

Design class	EKA 1 A	EKA 1 B	EKA 2	EKA 3
Designation	Long-distance motorway	Inter-regional motorway	Motorway-like road	Urban motorway
Signing	Z 330 StVO (motorway)		Z 331 StVO (trunk road)	Z 330 or Z 331 StVO
Directional signing	Blue		Yellow	Blue, yellow
Maximum permissible speed*	None		None	≤ 100 km per hour
Recommended distance between junctions	> 8,000 m	> 5,000 m	> 5,000 m	None
Traffic management around construction works on four-lane roads	4+0 generally necessary**		4+0 not absolutely necessary	

* see explanation given in Section 3.4

** ‘4+0’ indicates the lane configuration during reconstruction. The ‘4’ indicates that four lanes (two in each direction) will be accommodated on the one carriageway and the ‘0’ indicates that there will be no traffic on the other carriageway while it is being reconstructed.

3.4 Speeds

In accordance with the specifications of these guidelines, EKA 1 motorways are designed in such a way that a speed limit is not necessary. The recommended speed of 130 km/h applies.

When designing EKA 1 and EKA 2 motorways, if it is necessary to include curve radii close to the limiting values on a stretch of road that otherwise allows for higher speeds, the introduction of a speed limit for these sections that applies in particular in wet weather can be considered in consultation with the traffic authority.

A restriction such as this is usually not necessary if the geometry of the motorway features values close to the limit values over long stretches of road.

The calculation of the limiting values for the design elements (see Section 5) is based on the following speeds in the wet:

- 130 km/h for long-distance motorways (EKA 1 A),
- 120 km/h for inter-regional motorways (EKA 1 B),
- 100 km/h for motorway-like roads (EKA 2), and
- 80 km/h for urban motorways (EKA 3).

EKA 3 motorways are characterized by the fact that a speed limit applies universally on them. If the geometry of these motorways is based around the limiting values for EKA 3, the speed limit is generally 80 km/h; if it is based on significantly higher values the speed limit can, as an exception, be 100 km/h. However, even in these cases, a maximum permissible speed of 80 km/h is generally acceptable because of the narrower lane width, the smaller distances between junctions, and the associated orientation problems relating to directional signing and the frequency of weaving manoeuvres.

A maximum permissible speed should be specified at the planning stage, only when, in one of the cases described above, it is clear that the road cannot be operated safely without a speed limit because of physical restrictions that cannot be eliminated making the design marginal.

Moreover, only in these cases is it justifiable to base the calculation of the rating level for traffic noise on this speed limit. Apart from that, technical noise calculations should be conducted for the recommended speed of 130 km/h on motorways. This also applies to cases where a speed limit applied until such time as the road was improved, because the purpose of improving the road is to eliminate the need for a speed limit.

At junctions, the same maximum permissible speed applies to mainline carriageways without weaving lanes (continuous lanes on which no weaving occurs) as applies to the open motorway sections.

4 Cross-sections

4.1 General remarks

The selection of cross-section components and the specification of dimensions for standard motorway cross-sections are important qualities that affect:

- road safety,
- quality of traffic flow, and
- construction, operation, and maintenance requirements.

Standard cross-sections are determined by the forecast traffic volume and the desired quality of traffic flow.

Once the standard cross-section has been selected, the design planning stage provides evidence of the traffic flow quality that can be achieved under the given road and traffic conditions on the basis of the HBS and the quality requirements of the RIN. Changes may need to be made, e.g. the addition of lanes on ascending gradients on certain sections of the motorway. In particularly complex situations (e.g. in urban areas), traffic flow simulations may be necessary.

Finally, the compatibility of road cross-sections in different consecutive operation sections, improved sections, or new sections must also be checked to ensure that road characteristics are as uniform as possible and transitions are safe and identifiable for drivers.

In the case of EKA 3 motorways, particular attention must be paid to their integration into their urban surroundings. Possible ways of integrating such cross-sections are presented in Appendix 1.

4.2 The fundamental principles of determining cross-section dimensions

4.2.1 Standard vehicle dimensions

According to the StVZO, the maximum permissible dimensions for motor vehicles are a width of 2.55 m (exception: 2.60 m for refrigerated vehicles), a height of 4.00 m, and a length of 16.50 m (articulated trucks) or 18.75 m (road trains).

4.2.2 Roadway components

4.2.2.1 Traffic space

The **traffic space** comprises the space taken up by the vehicle, the lateral and overhead clearance, and the space above the hardstrip and hard shoulder (Fig. 1).

The **lateral clearance** is the space available to heavy vehicles as defined in Section 4.2.1 for the accommodation of minor driving and steering inaccuracies and protruding vehicle parts (e.g. mirrors). Depending on the lane, it measures 0.70 m, 0.95 m, or 1.20 m.

The **overhead clearance** is the space available to a moving vehicle to accommodate loading inaccuracies and vehicles bouncing on uneven road surfaces. It measures 0.25 m.

4.2.2.2 Clearance

The **clearance** comprises the traffic space and the overhead and lateral safety spaces (Fig. 1).

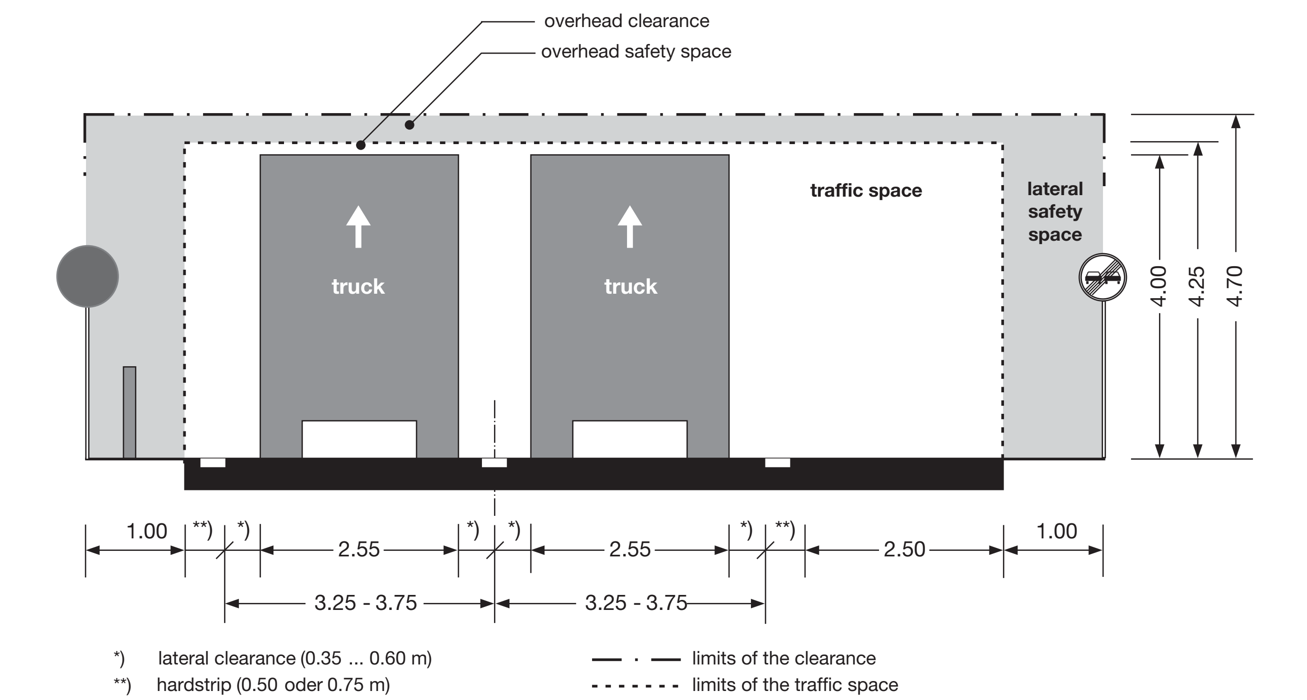


Fig. 1: Basic dimensions of the traffic space and the clearance (dimensions in [m])

The **lateral safety space** has a standard width of 1.00 m. If the motorway has no hard shoulder, this width shall be increased to 1.25 m.

The **overhead safety space** on motorways is 0.45 m high. This means that the height of the total clearance is 4.70 m. This dimension already comprises a buffer of 0.20 m to allow for the future rehabilitation of the pavement using overlays.

Total clearances are vertical and must be applied within the lateral limits.

The design clearance space must be kept clear of obstacles. Protective devices and easily deformable parts of street furniture may protrude into the clearance and come within 0.50 m of the traffic space. In cases where space is at a premium and there are no alternative ways of installing the necessary protective devices, these can protrude into the clearance to within 0.25 m of the traffic space. The central axis of traffic sign and street furniture posts (∅ < 76 mm) may be positioned at the boundary of the clearance. Kerbs may protrude into the clearance right up to the limit of the traffic space (Section 8.7).

For special instructions relating to tunnel sections, please refer to the Guidelines for the Equipment and Operation of Road Tunnels (*Richtlinien fur die Ausstattung und den Betrieb von Straßentunneln*, RABT) and Section 8.5.

4.2.3 Standard cross-section components

4.2.3.1 Carriageway and paved width

The **carriageway** comprises the lanes and the hardstrip. Hard shoulders (marginal strips) are not part of the carriageway.

Together, the carriageway and the hard shoulder make up the **paved width**. The paved width is equal to the width of the traffic space.

- The actual width of the paved width is specified for the different approaches to lane operation around construction works (Section 8.7):
- 4+0 lane operation: 12.00 m
- 5+0-/5+1 lane operation: 14.50 m
- 6+0-/6+2 lane operation: 17.00 m

These requirements determine the dimensions of the standard cross-sections RQ 31 and RQ 36.

4.2.3.2 Lanes

Lanes that are predominantly used by heavy vehicles should preferably be 3.75 m wide in order to ensure an even distribution of the load on the carriageway. In the case of EKA 1 motorways with four and six lanes, this corresponds to the right-hand lane; in the case of motorways with eight lanes, the two right-hand lanes.

The left-hand lanes on EKA 1 motorways, which are not used as frequently by heavy vehicles, are 3.50 m wide (exception: RQ 31 in accordance with Section 4.3.2).

As a rule, all lanes on EKA 2 motorways and the right-hand lanes on EKA 3 motorways must be 3.50 m wide (to reduce construction costs and space requirements respectively). Lanes that are not predominantly used by heavy vehicles, i.e. the left-hand and middle lanes on EKA 3 motorways, must be 3.25 m wide.

In accordance with Section 8.1, climbing lanes on ascending gradients must be 3.50 m wide.

For instructions on the design of cross-sections for merging and diverging lanes at junctions, please refer to Section 6.4.

4.2.3.3 Hardstrips

Hardstrips are not driven on. They are used to stabilize the edge of the carriageway and as a base for markings that indicate the edge of the carriageway. They are generally 0.50 m wide.

Hardstrips bordering the central reserve on EKA 1 motorways are 0.75 m wide. This increases the sight distance at left-hand curves. It also means that vehicle occupants can get out of the car at the central reserve in the case of emergency stops. Hard strips are also widened to 0.75 m in cases where a wider hard strip would provide the width required for the specific issue of lane operations around roadworks (Section 8.7).

4.2.3.4 Kerbs and draining channels

For motorways, open drainage via the verge and into the surrounding ground is preferable. Where possible, kerbs and gutters should not be used because (raised) kerbs constitute obstacles.

If, however, a flush kerb is necessary (e.g. in water protection areas or areas where the soil does not allow for infiltration), it must be constructed at the edge of the hard shoulder in such a way that the drainage infrastructure is located outside the hard shoulder. Drainage infrastructure in the central reserve takes precedence over maintaining the width of the central reserve. Please observe the instructions in Section 8.10.2.

4.2.3.5 Hard shoulders

For reasons of traffic safety and road operation, hard shoulders (marginal strips) are an indispensable part of motorway cross-sections. In order to ensure that they can be used by heavy trucks in the event of roadworks or incidents, they have the same pavement structure as traffic lanes.

In order to allow trucks to be parked safely, hard shoulders must be at least 2.50 m wide. For this reason, this width is stipulated for EKA 1 and EKA 2 motorways. A hard shoulder width of 2.00 m is sufficient for the parking of a passenger car. This width is stipulated for EKA 3 motorways.

In the case of the four-lane cross-section of an EKA 1 motorway (RQ 31), the paved width (Sections 4.2.3.1 and 8.7) is dimensioned as follows to allow for 4+0 lane operation around roadworks: the hard shoulder must be 3.00 m wide and the hardstrip 0.75 m wide so that, together, they can be used as a temporary lane in the event of heavy traffic (Section 8.8).

4.2.3.6 Central reserves

- Central reserves separate carriageways and are used as a site for engineering structures and traffic engineering facilities such as:
- supports for overpasses,
- vehicle restraint systems,
- gantry posts,
- lighting columns,
- traffic signs,
- drainage equipment, and
- where necessary, anti-glare systems.

Central reserves are generally 4.00 m wide. This width not only provides enough space for the structures and facilities listed above, but also for planting and landscaping (Section 7.7).

In view of the shortage of available space, the central reserve on EKA 3 motorways is 2.50 m wide. This makes considerable demands on vehicle restraint systems. This width can be used as long as no supports for overpasses have to be constructed on the central reserve. If such supports are necessary, the central reserve must be widened accordingly.

A width of 2.50 m is not suitable for planting.

4.2.3.7 Verges

- Verges are used as a site for the following items of street furniture:
- vehicle restraint systems,
- gantry posts,
- traffic guidance equipment, and
- traffic signs.

They are also the workplace of operation and maintenance services. Verges must be stable. As a rule, they are 1.50 m wide.

If no vehicle restraint systems are necessary on motorways (and on slip roads at junctions) in cuts with standard slope gradients or if there is a noise bund with a standard slope gradient alongside the motorway, the width of the verge can be reduced by 0.50 m. In this case, the necessary stopping sight distance (Section 5.5) must be met and the lateral safety space (Section 4.2.2.2) must be kept free. The minimum width of 1.00 m must be observed.

4.2.3.8 Separating strips

Separating strips separate the traffic space for through traffic from a link road/slip road. The separating strip is 3.00 m wide.

4.2.4 Construction of slopes

Slopes are generally constructed as illustrated in Fig. 2.

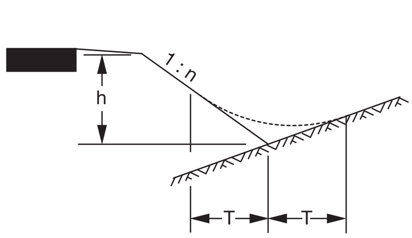
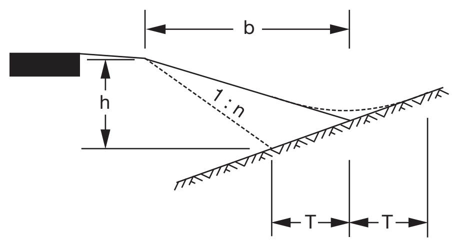
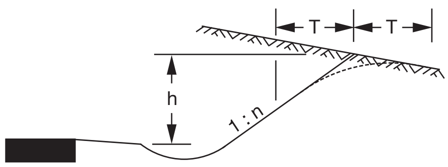
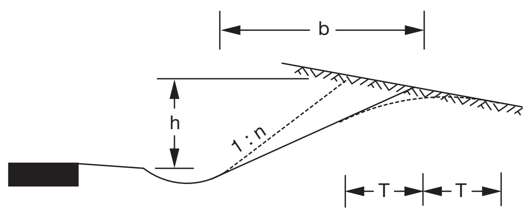
	Slope height h h ≥ 2.0 m	Slope height h h < 2.0 m
Embankment		
Cut		
Slope	Standard slope gradient 1 : 1.5	Standard slope width b = 3.00 m
Half width of the rounding	T = 3.00 m	T = 1.5 h

Fig. 2: Construction of standards slopes

It may be necessary to opt for a different slope gradient and slope design

- for reasons relating to soil properties,
- in order to integrate the motorway into the landscape,
- for reasons relating to emission control, and
- in order to avoid snow drifts.

In the case of high slopes (approx. h greater than or equal to 5.00 m), it may be necessary to construct berms in order to ensure the stability of the slope or to facilitate the upkeep of green areas. At least the longer berms should have a width, b, of 3.0 m and should be able to support vehicular traffic to allow for road operation services.

The transition between a slope and the surrounding land should be rounded off in accordance with Fig. 2. For information of the drainage of the foot of a slope, please refer to Section 8.10.

4.3 Standard cross-sections

4.3.1 General remarks

In order to ensure the uniform design of motorways in the same design class, only one standard cross-section has been specified for four-, six-, and eight-lane motorways.

The selected standard cross-section should be maintained for all continuous sections of the network with the same link function level.

4.3.2 Standard cross-sections for EKA 1 motorways

The standard cross-sections for EKA 1 motorways are shown in Fig. 3.

The relevant areas of application can be derived from Fig. 4. The shaded area of the bars in the graph corresponds to the traffic volume range for which the standard cross-section is generally suitable. In the pale areas at the edges of the bars, further criteria (Section 4.4) determine the possible areas of application.

In exceptional circumstances, RQ 28 can be considered for EKA 1 B in accordance with Section 4.3.3 as long as 4+0 lane operation will not be necessary around roadworks. This may be possible, for example, in the case of forecast traffic volumes of less than 30,000 vehicles/24 h (in both directions).

4.3.3 Standard cross-sections for EKA 2 motorways

In accordance with Fig. 5, the standard cross-section for an EKA 2 motorway is RQ 28.

If 4+0 lane operation around roadworks becomes necessary, e.g. for forecast traffic volumes of over 30,000 vehicles/24 h (in both directions), RQ 31 should be used in accordance with EKA 1.

As a six-lane cross-section, the standard cross-section RQ 36 can, if necessary, be used in accordance with Section 4.3.2 if the forecast traffic volume is greater than 60,000 vehicles/24 h (in both directions).

4.3.4 Standard cross-sections for EKA 3 motorways

Because of the shortage of available space in built-up areas and the lower speeds, EKA 3 motorway cross-sections have smaller dimensions (Fig. 6).

In exceptional cases, the hard shoulder can be dispensed with over a limited distance. In this case, emergency lay-bys (break down bays) are necessary for reasons of safety. Emergency lay-bys that are 80m long (including tapers) should be 3.00 m wide. Emergency lay-bys should not be situated more than 1,000 m apart.

If the motorway is designed without hard shoulders, the verge should be widened to at least 2.00 m, paved, and the vehicle restraint systems can be moved back in order to make it possible to at least park a passenger car alongside the carriageway. This approach can be used either as an alternative to or in combination with emergency lay-bys.

Fig. 7 shows the areas of application for the standard cross-sections for EKA 3 motorways.

4.4 Checking the standard cross-section

The choice of standard cross-section in accordance with Section 4.3 must be checked to make sure that it is appropriate for the prevailing marginal planning conditions. The choice of standard cross-section has significant impacts on:

- an assessment of the traffic flow quality in accordance with the HBS, taking into consideration the forecast traffic volume, the proportion of heavy vehicle traffic, the position of the motorway in relation to built-up areas, the speed limit, and the vertical alignment of the road;
- the specifications of the RIN regarding the desired passenger car travel speed in relation to the road category; and
- the requirements regarding lane operation around roadworks.

It may be necessary to introduce climbing lanes on ascending gradients on certain sections of the motorway (Section 8.1).

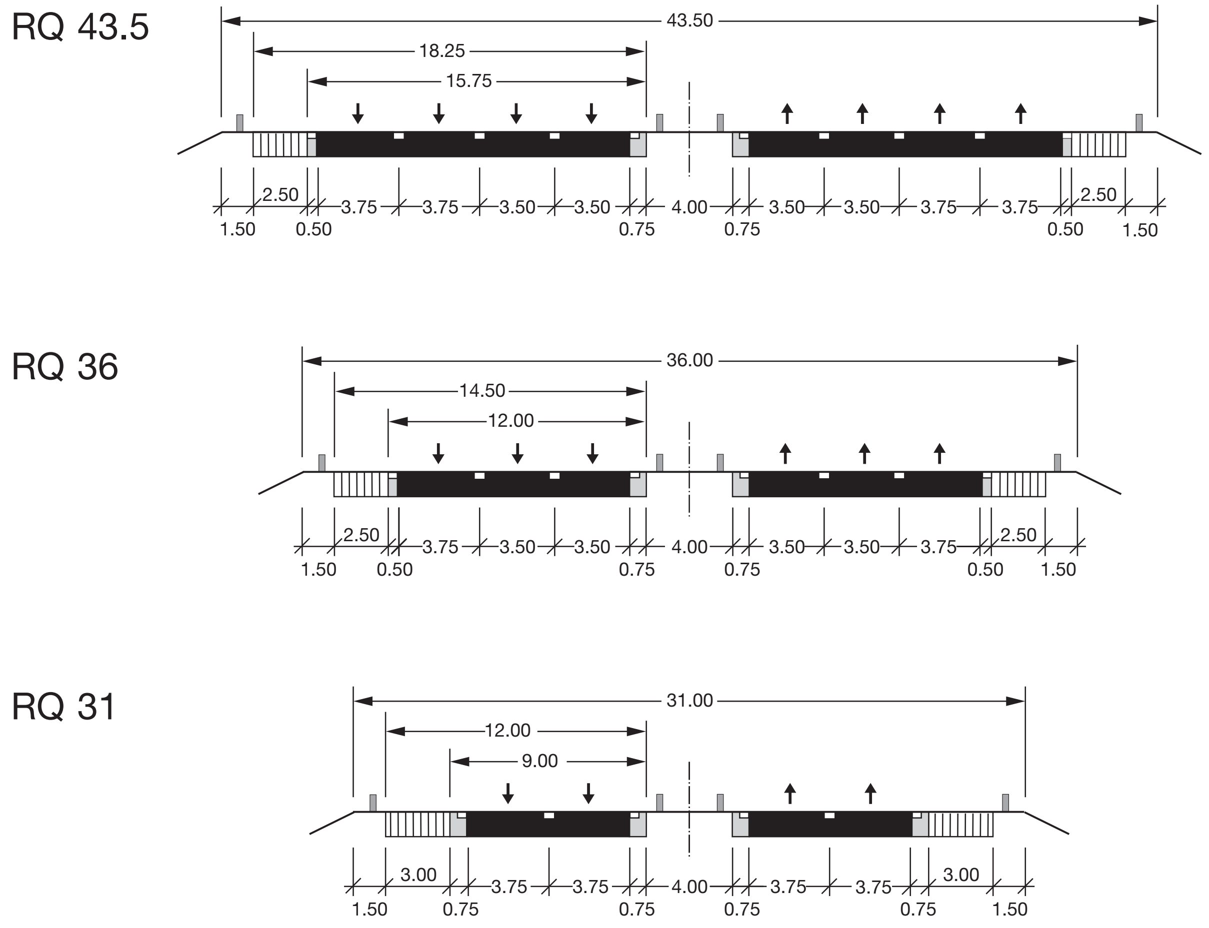


Fig. 3: Standard cross-sections for EKA 1 motorways (dimensions in [m])

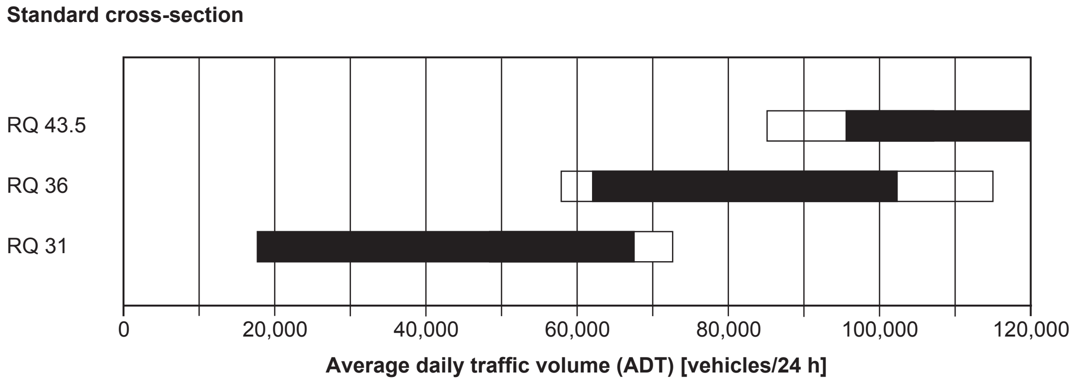


Fig. 4: Areas of application for EKA 1 motorway standard cross-sections

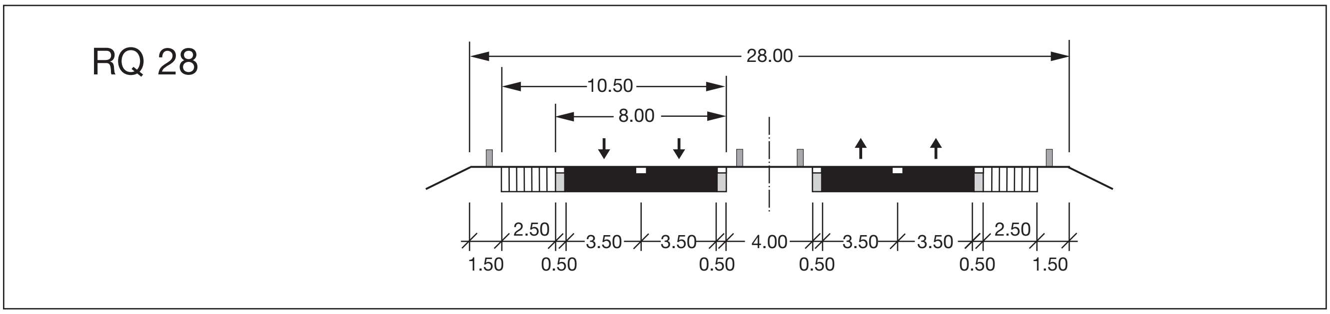


Fig. 5: Standard cross-section for EKA 2 motorways (dimensions in [m])

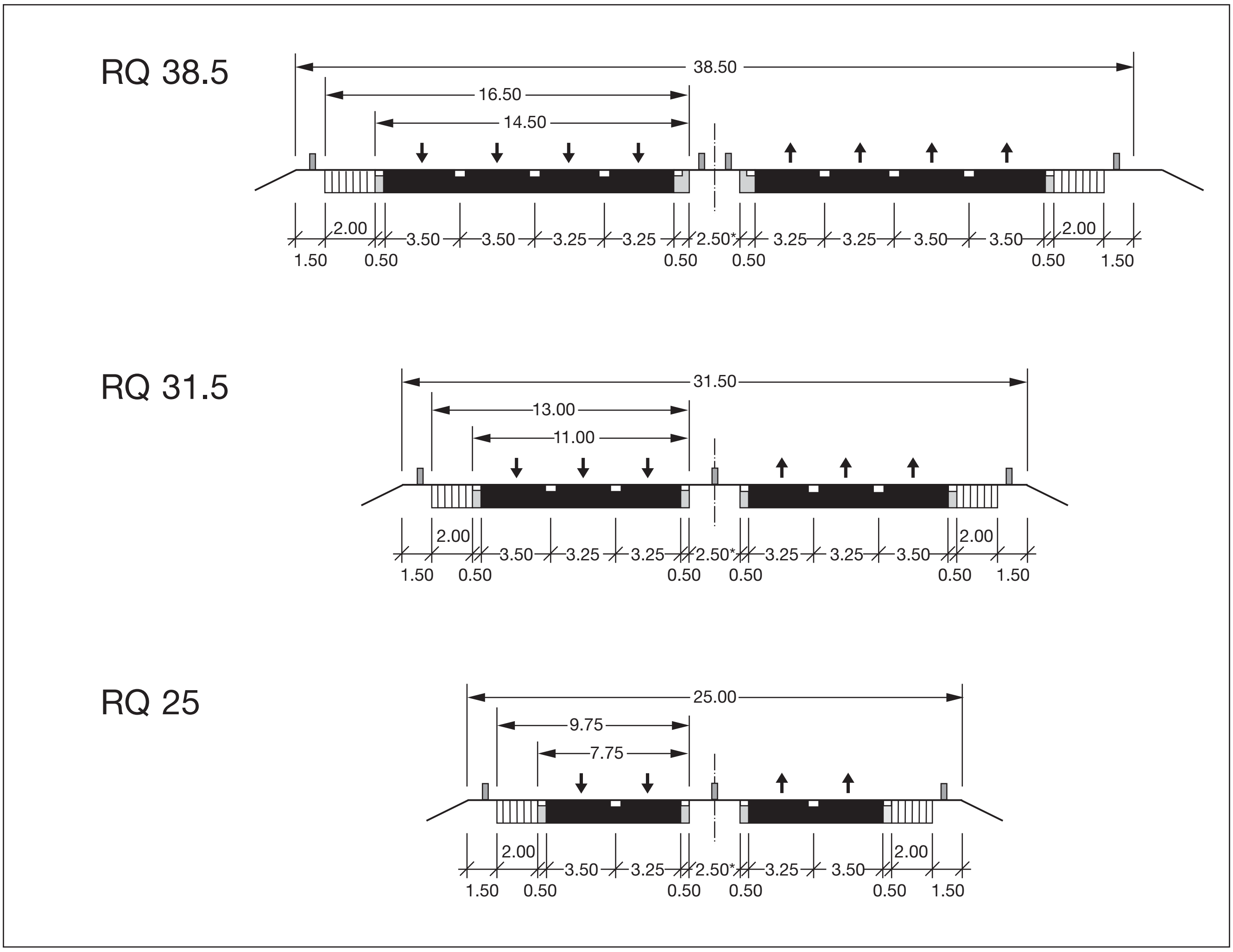


Fig. 6: Standard cross-section for EKA 3 motorways (dimensions in [m])

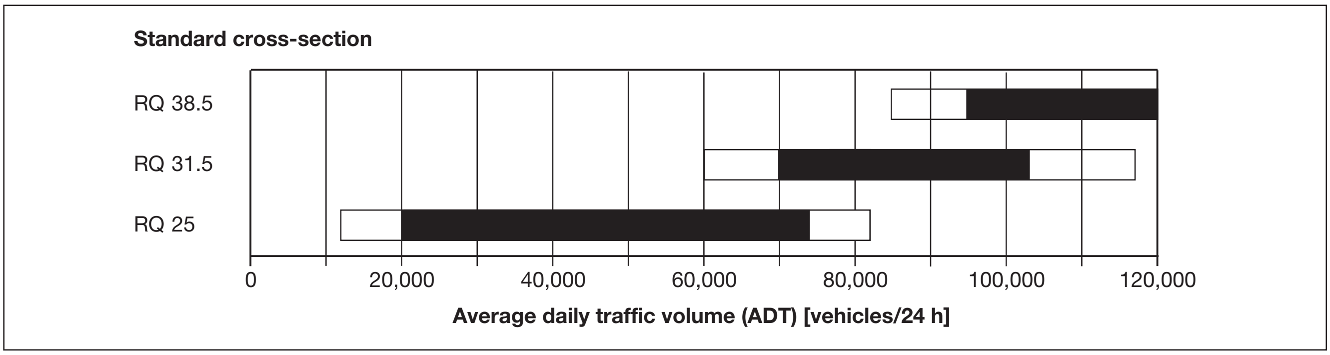


Fig. 7: Areas of application for EKA 3 motorway standard cross-sections

4.5 Cross-sections on bridges

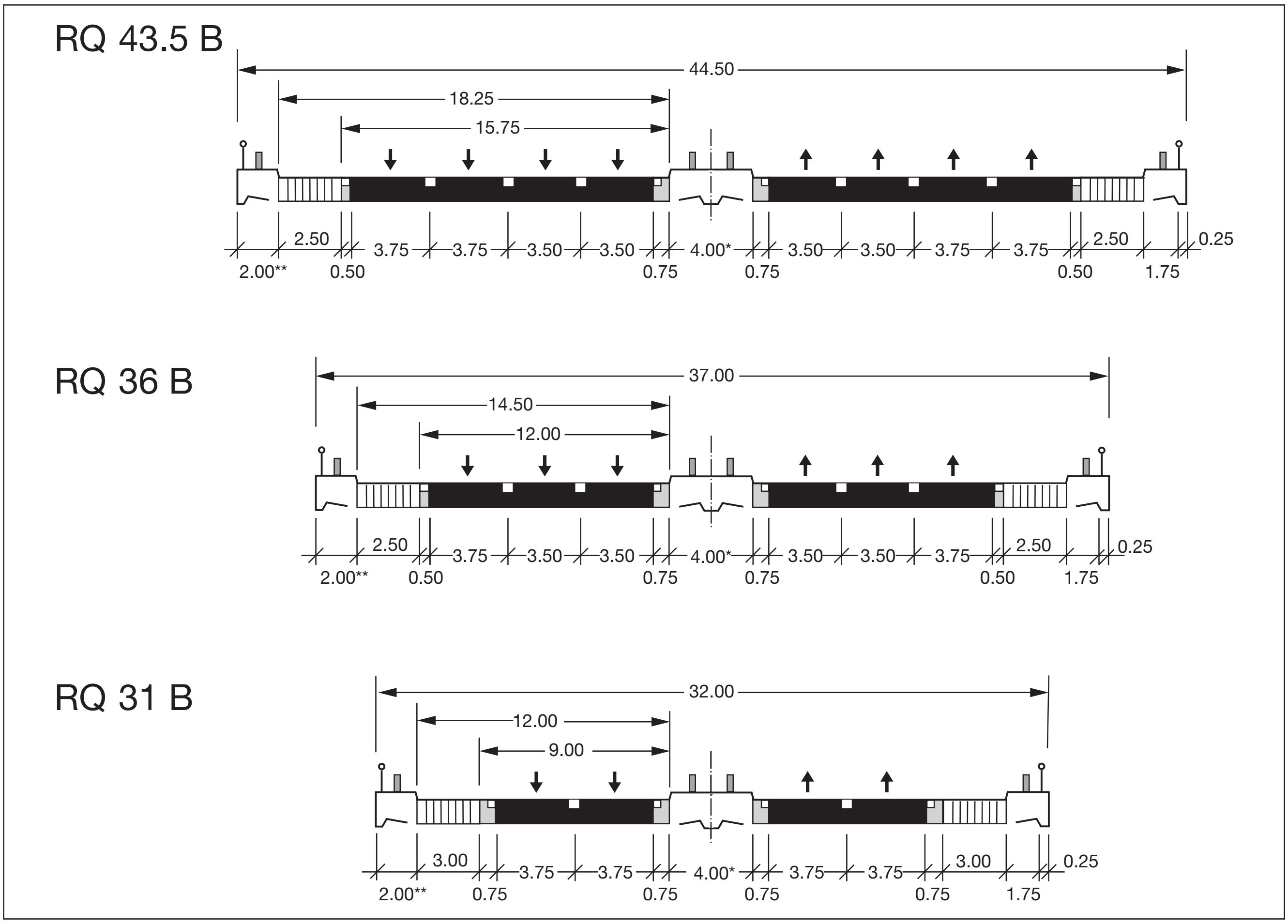
Special instructions apply for standard cross-sections around bridges. In these cases, the widths of the cross-section elements should, as a rule, be the same of those of the connecting sections of road.

If the cross-section dimensions differ from each other, the necessary tapers are constructed in accordance with Section 5.6.4.

Fig. 8 shows the structure of standard cross-sections for EKA 1 motorways on bridges.

For EKA 2 motorways, the standard cross-section RQ 31 B outlined in Fig. 8 is recommended in order to allow for 4+0 lane operation in the event of bridge rehabilitation even if the cross-section RQ 28 was chosen on the road despite an ADT of greater than 30,000 vehicles/24 h (in both directions).

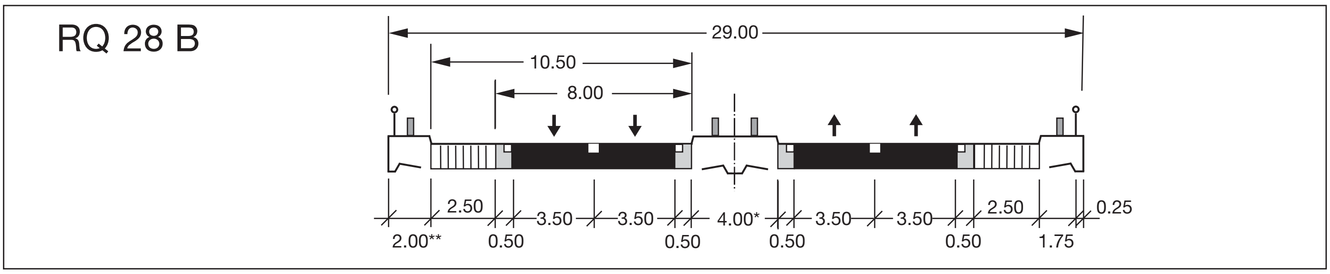
Insofar as 4+0 lane operation is not required for low traffic volume (Section 4.3.3), it is possible to choose RQ 28 B in accordance with Fig. 9. This cross-section may only be considered for traffic volumes of up to a maximum of 30,000 vehicles/24 h.



*) If the clear span between the abutments of a bridge is more than 100 m, the raised medians should have a total width of 3.5 m.

**) In accordance with RiZ-ING, depending on the passive safety systems chosen, the width of the raised sections, and thereby the total width of the bridge, can change.

Fig. 8: Construction of standard cross-sections for EKA 1 motorways on bridges (dimensions in [m])



*) If the clear span between the abutments of a bridge is more than 100 m, the centre caps should have a total width of 3.5 m.

**) in accordance with RiZ-ING, depending on the passive safety systems chosen, the width of the caps, and thereby the total width of the bridge, can change.

Fig. 9: Construction of standard cross-sections for EKA 2 motorways on bridges (dimensions in [m])

Fig. 10 shows the standard cross-sections for EKA 3 motorways on bridges.

As a rule, water is drained from bridges using 0.50-m wide gutters.

In the cross-section, vehicle restraint systems around structures are provided for in accordance with the corresponding standard design drawings from the Federal Ministry of Transport, Building and Urban Development.

4.6 Cross-sections in tunnels

The choice of tunnel cross-section depends on the traffic volume and the chosen design. The standard cross-sections for tunnels are presented in Fig. 11.

Tunnels cost much more to build and operate than open roads. For this reason, the dimensions of standard tunnel cross-sections are smaller than standard cross-sections on the open road. The distance between the carriageways is based on structural considerations and each carriageway occupies a separate tunnel tube. The carriageway axes and edges of the carriageway at the start and the end of the tunnel must be tapered accordingly.

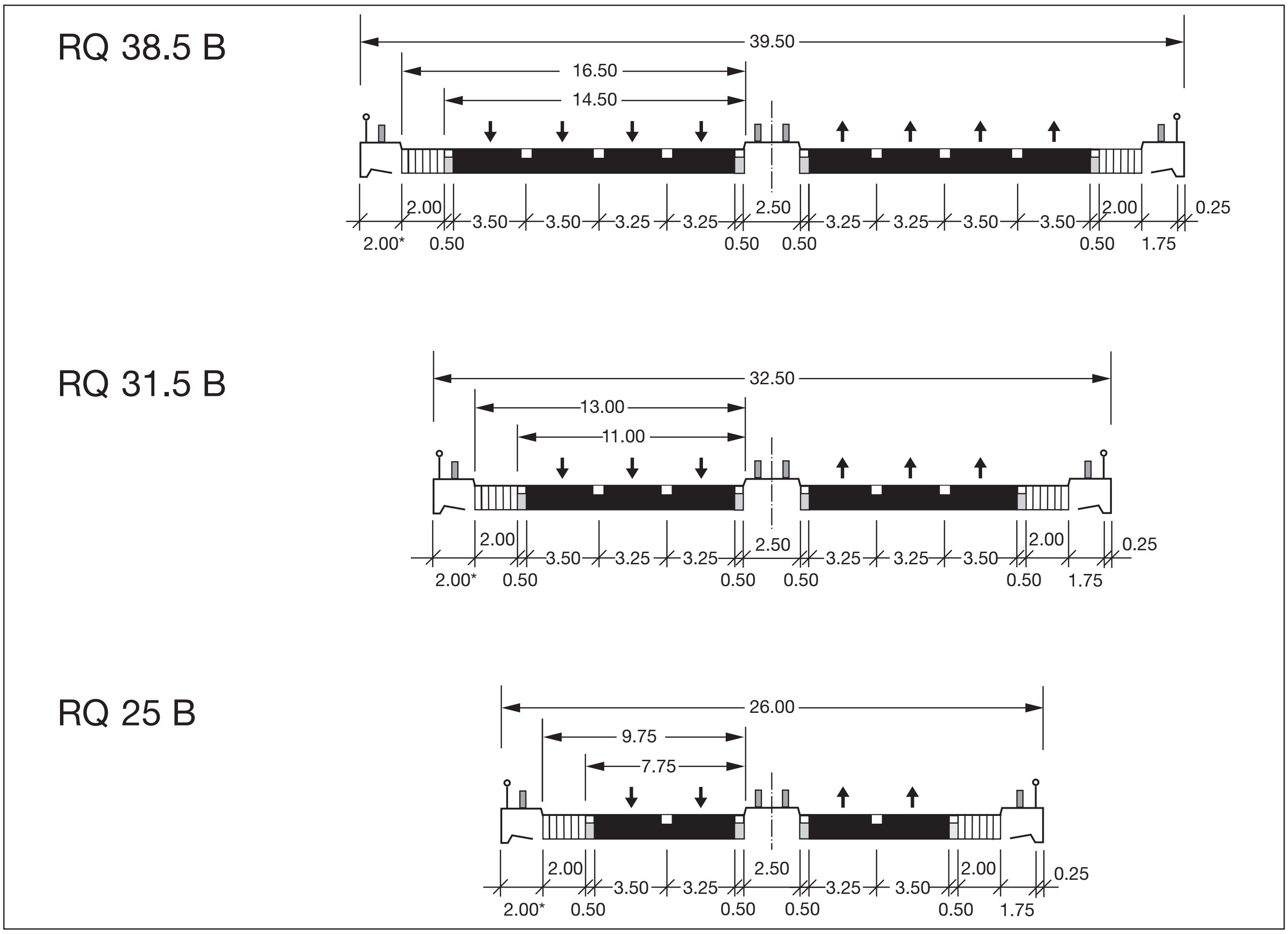
There are several possible tunnel cross-sections for every standard cross-section on the open road (Table 11).

Alternatively, on EKA 3 motorways, the lane widths of the respective standard cross-sections on the open road should be maintained.

The tunnel cross-section is selected in accordance with the Procedure for Selecting Road Cross-sections in Tunnels (*Verfahren fur die Auswahl von Straßenquerschnitten in Tunneln*, BMV ARS 6/2000).

Initially, for planning purposes, a standard cross-section without hard shoulders with the designation ‘t’ should be assumed. As a rule, when evaluating traffic flow, road safety, and cost considerations, larger cross-sections with hard shoulders ‘T’ only come into consideration for traffic volumes across the entire cross-section of more than 50,000 vehicles/24 h (in both directions) for two-lane carriageways and of more than 110,000 vehicles/24 h (in both directions) for three-lane carriageways (BMV ARS 6/2000).

The planning and design of road tunnels is regulated by the Guidelines for the Equipment and Operation of Road Tunnels (RABT). Section 8.5 contains supplementary technical information relating to design.

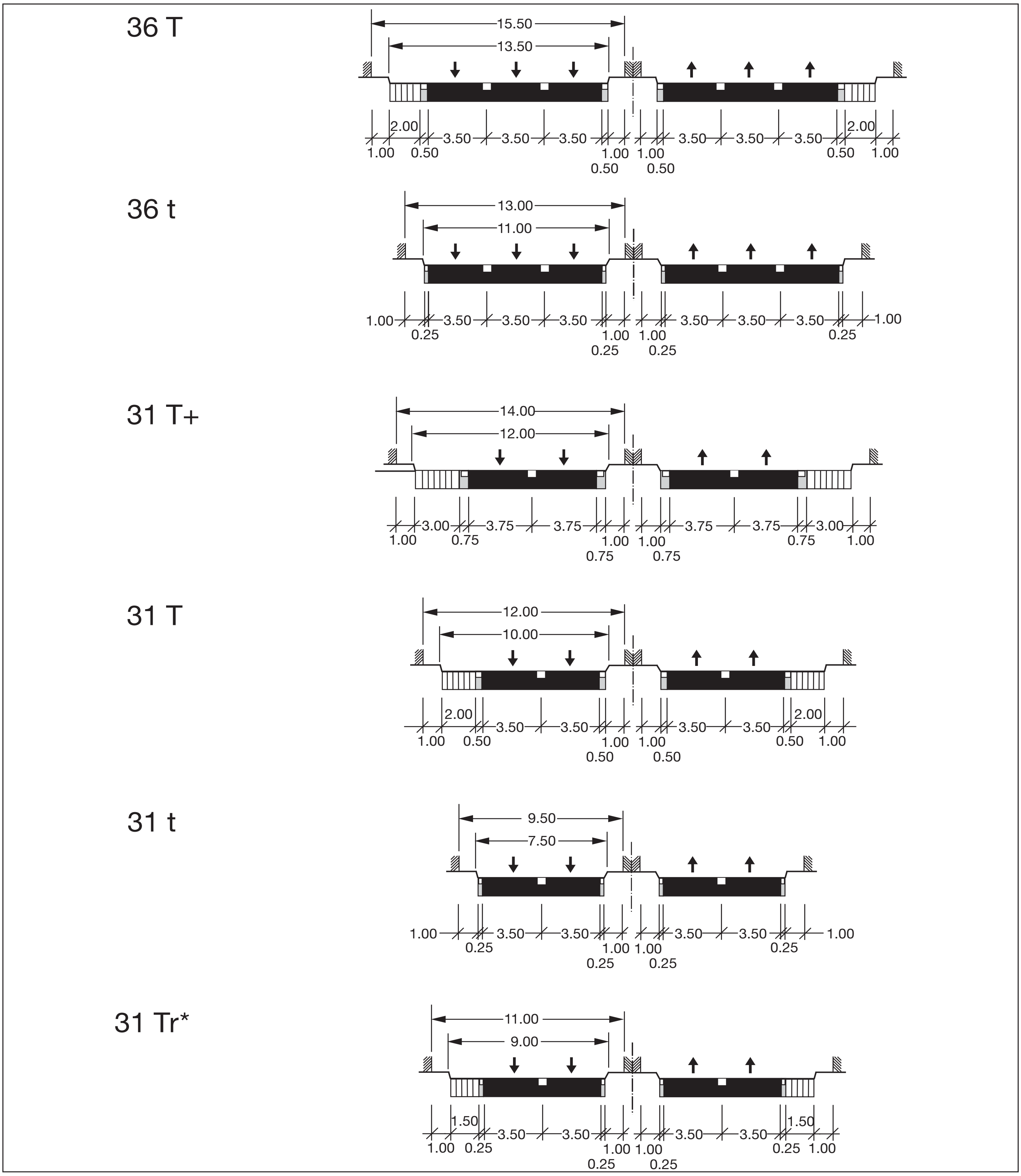


*) In accordance with RiZ-ING, depending on the passive safety systems chosen, the width of the caps, and thereby the total width of the bridge, can change.

Fig. 10: Construction of standard cross-sections for EKA 3 motorways on bridges (dimensions in [m])

Table 11: Allocation of tunnel cross-sections to standard cross-sections on the open road

Open road	Tunnel	RABT
RQ 36 RQ 31.5	36 t standard solution without hard shoulders 36 T standard solution with hard shoulders	33 t 33 T
RQ 31 RQ 28 RQ 25	31 T standard solution with hard shoulders 31 t standard solution without hard shoulders (with emergency lay-bys) 31 Tr alternative for shield tunnelling 31 T+ special solution for 4+0 lane operation around roadworks	26 T 26 t 26 Tr (29,5 T)



*) alternative to 31 t for shield tunnelling

Fig. 11: Construction of standard cross-sections motorways in tunnels (dimensions in [m])

5 Alignment

5.1 General remarks

The dimensions of the design elements for the alignment of motorways shall be based on safety considerations and vehicle dynamics.

Elements for EKA 1 A motorway links shall be designed in such a way as to allow vehicles to travel safely at 130 km/h in wet conditions. EKA 1 B and EKA 2 motorways generally need to be adapted more to suit the surrounding terrain and therefore require a less expensive alignment design. EKA 3 motorways are subject to other marginal technical design and traffic conditions; speed limits generally apply on them.

– The limit values or minimum values for the design elements, which are determined by vehicle dynamics, are set on the basis of the following 'wet weather' speeds:
– for long-distance motorways (EKA 1 A): 130 km/h
– for inter-regional motorways (EKA 1 B): 120 km/h
– for motorway-like roads (EKA 2): 100 km/h
– for urban motorways (EKA 3): 80 km/h.

For more information on considerations regarding the introduction of necessary speed limit restrictions in consultation with traffic authorities, please refer to Section 3.4.

The horizontal and vertical alignments shall be co-ordinated, taking the principles of three-dimensional alignment into account (Section 5.4). Particular care shall be taken in this regard in the case of the improvement of motorways when existing infrastructure is used. In such cases – particularly those in uneven terrain – improvements in the gradient generally result in higher speeds, which also frequently require the horizontal alignment to be changed.

Once the axis and the gradient have been specified, the alignment shall also be checked to determine whether the necessary stopping sight distance is provided. The stopping sight distance also depends on the recommended speed or, where applicable, the speed limit.

5.2 Horizontal alignment

5.2.1 Straights

– As design elements, straights can be expedient
– in appropriate landscape surroundings, e.g. on level ground and in wide valleys,
– around entries and exits at junctions or at ancillary facilities,
– when improving and widening existing motorways,
– when aligning the route around local constraint lines, and
– when integrating the motorway into an urban environment.
– The disadvantage of having long straights – in particular those with continual gradients – is that they
– only rarely allow for a harmonious, flowing alignment,
– make it more difficult to estimate distances and the speeds of vehicles travelling both ahead and behind,
– encourage the driver to travel very fast, and
– reduce road safety through monotony and the risk of fatigue.

For this reason, it is recommended that the length of straights be restricted to max

$$L = 2{,}000 \text{ m} \quad (1).$$

The larger the design elements that border on long straights, the more harmonious the transition between the elements.

Short straights between curves that curve in the same direction should be avoided. If this is not possible, the minimum length should be

$$L = 400 \text{ m} \quad (2)$$

in order to ensure that the short straight between the two curves appears as a design element in its own right.

5.2.2 Circular curves

The radii of circular curves should be large enough to ensure that their size and spacing follow the topography and the elements that shape the surrounding area closely. Because of landscape conservation or, in the case of EKA 3 motorways, town planning considerations, circular curves shall be co-ordinated carefully on a case-by-case basis with the land use requirements of the surrounding land and with a view to creating a harmonious three-dimensional alignment.

The minimum radii for circular curves are given in Table 12. Appendix 3 contains the basic principles for calculating curve radii.

In order to ensure that drivers do not have to steer in one direction and then the other in quick succession, minimum circular curve lengths (Table 12) should also be observed.

Table 12: Minimum radii (where q = 6.0 %) and minimum lengths for circular curves

Design class	**min R** [m]	**min L** [m]
EKA 1 A	900	75
EKA 1 B	720	
EKA 2	470	55
EKA 3	280	

The co-ordination of consecutive circular curve radii promotes consistent speed and, consequently, safe driver behaviour. For this reason, it is recommended that the condition

$$R_1/R_2 \leq 1.5 \quad (3)$$

be fulfilled if R_1 is less than or equal to 1,500 m. Here R_1 is the first curve and R_2 is the second curve in the direction of traffic flow.

On motorways without speed limits, long straights lead to very high speeds. For this reason, a minimum radius of

$$\min R = 1{,}300 \text{ m} \quad (4)$$

should be observed at the end of straights of L_G greater than 500 m in length.

5.2.3 Transition curves

- Transition curves are provided between circular curves and between straights and circular curves. The purpose of transition curves is:
- to allow for superelevation development between the different crossfalls;
- to allow for gradual steering in and out of the curve and in so doing
- to ensure a continual change in the centrifugal acceleration that occurs when driving in a curve; and
- to create a swift and optically satisfactory alignment by gradually changing the curvature.

Transition curves shall be in the form of a clothoid (Appendix 4). The following clothoid parameters ensure that transition curves meet the requirements listed above:

$$\frac{R}{3} \leq A \leq R \quad (5)$$

Table 13: Minimum parameters for clothoids

Design class	**min A** [m]
EKA 1 A	300
EKA 1 B	240
EKA 2	160
EKA 3	90

Transition curves are necessary on all motorways. The only exceptions to this rule are cases where a slight change in the angle of the curve (γ is less than 10 gon or 9°, flat curve) makes it impossible to have a transition curve followed by a circular curve followed by a transition curve. In this case, the minimum curve length, L_{min}, should be 300 m.

Fig. 12 shows the various element sequences in which transition curves are used.

The **simple clothoid** forms the transition from a straight to a circular curve.

The **reverse clothoid** comprises two clothoid arms that meet at their respective origins and curve in opposite directions, and which both fulfil the conditions for a

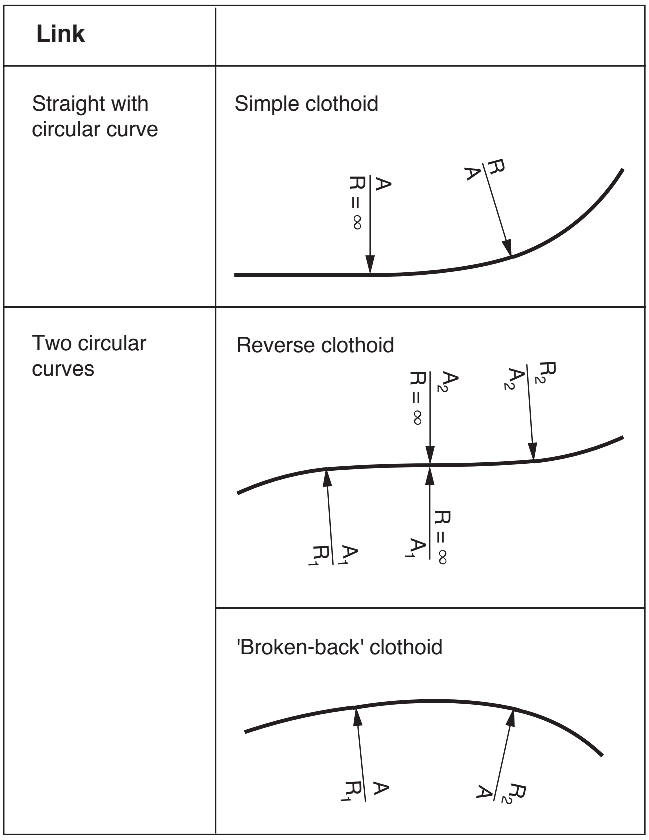


Fig. 12: Situations in which transition curves are used

simple clothoid. In the interest of producing a harmonious alignment and an even rate of change in superelevation, both arms of the clothoid should have similar parameters.

If the parameters are not the same, the ratio

$$A_1 \leq 1.5 \cdot A_2 \quad (6)$$

should apply if A_2 less than or equal to 300 m.

The **'broken-back' clothoid** is a section of a clothoid connecting two circular curves with different radii that curve in the same direction. The circle curves must not touch and may not have the same centre point. In order to ensure that the 'broken-back' clothoid is discernible, the change in direction should be t greater than or equal to 3.5 gon (3.1°).

Compound curves (no 'broken-back' clothoid between circular curves with different radii that curve in the same direction) are not permissible.

5.3 Vertical alignment

5.3.1 Longitudinal gradients

- Gradual longitudinal gradients
- increase road safety (this is a general statement and an exception is near areas of change in superelevation where the crossfall passes through zero),
- increase traffic flow quality,
- reduce operating costs and road user costs, and
- reduce emissions.

– On the other hand, steeper longitudinal gradients can be used to
– improve the adaptation of the motorway to suit the surrounding terrain,
– reduce the impact on the surrounding area and the landscape, and
– cut construction costs.

Table 14 lists the maximum longitudinal gradients for the different motorway design classes.

Table 14: Maximum longitudinal gradients

Design class	**max s** [%]
EKA 1 A	4,0
EKA 1 B	4,5
EKA 2	4,5
EKA 3	6,0

On ascending gradients with a length, L, greater than 500 m and longitudinal gradients, s, greater than 2.0 %, a check must be done to determine whether climbing lanes in accordance with Section 8.1 are necessary.

For information of longitudinal gradients in tunnels, please refer to Section 8.5.

On superelevation development sections between crossfalls of opposite curvature, a longitudinal gradient of

$$s \geq 1.0\,\% \text{ (exception} \geq 0.7\,\%) \qquad (7)$$

shall be used as standard in order to avoid zones with poor drainage (Section 5.6.3.3).

In order to ensure highway drainage on bridges, the gradient shall as a rule be designed with a minimum longitudinal gradient, s, of 0.7 % (Section 8.4).

For motorway sections that are drained using gutters, a minimum longitudinal gradient, s, of 0.7 % is also recommended in order to ensure that the water drains away.

5.3.2 Crest and sag vertical curves

The diameters of crest and sag vertical curves should be selected in such a way that

– together with the horizontal alignment elements they create a balanced three-dimensional alignment,
– they ensure road safety by ensuring that stopping sight distances are met,
– they are adapted as well as possible to suit the surrounding topography and that they preserve the landscape, or, where applicable,
– take urban conditions into consideration (EKA 3).

The crest and sag vertical curves are in the form of quadratic parabolic curves. A characteristic of the size of the arc of the curve is the diameter of curvature, H, at the summit of the quadratic parabolic curve (Appendix 5).

The minimum values for the diameters of crest and sag vertical curves are given in Table 15.

Table 15: Minimum diameters for crests and sags

Design class	**Minimum diameter for crests H_K** [m]	**Minimum diameter for sags H_W** [m]
EKA 1 A	13,000	8,800
EKA 1 B	10,000	5,700
EKA 2	5,000	4,000
EKA 3	3,000	2,600

The minimum diameter for crests ensures that the required stopping sight distances to allow drivers to see the end of a queue in congestion is met (Appendix 6). They guarantee the stopping sight distance for horizontal straights. In horizontal curves and in cases where values fall below the minimum, spatial evidence shall be provided that the stopping sight distance is met.

The minimum diameters for sags ensure that the stopping sight distance is met, even under engineering structures. In the interest of harmonious road alignment, they should not, where possible, be less than half the diameter of the preceding crest

$$H_W \geq 0.5 \cdot H_K \qquad (8)$$

The minimum tangent lengths in Table 16 shall be observed.

Table 16: Minimum tangent lengths

Design class	**min T** [m]
EKA 1 A	150 (120*))
EKA 1 B	120
EKA 2	100
EKA 3	100

*) Exception: this value applies during reconstruction and improvement

5.4 Three-dimensional alignment

5.4.1 Elements of three-dimensional alignment

The roadway as seen by the driver comprises the pavement, slopes of cuttings and embankments, and the surrounding environment that does not actually belong to the motorway (but to the natural environment or populated area). The geometry of the roadway is specified by three separate aspects of designs: the horizontal alignment, the vertical alignment, and the cross-section.

In view of the fact that the road design comprises three different aspects, it is not always easy to appreciate the three-dimensional result. In order to get an idea of the 3D impact of the motorway, specific 3D elements are defined. Each of these elements comprises one horizontal and one vertical alignment element. For these standardized 3-D elements, perspective views of the roadway are provided in Fig. 13 (horizontal straight) and Fig. 14 (horizontal curve).

On the basis of these elements, these perspective views allow for a first, approximate assessment of the impact of the three-dimensional (or spatial) alignment.

A comprehensive inspection of the three-dimensional alignment is only possible using perspective views that are generated for each section of road that needs to be assessed. In this regard, the drivers' perspective is the only useful perspective view when it comes to evaluating the course of the road. Perspective views can be developed using appropriate planning programme modules and the digital models of the terrain and the road by including slopes in surrounding areas. The task of obtaining these perspective views must comply with the References on the Visualization of the Design of Rural Roads (*Hinweise zur Visualisierung von Entwürfen für außerörtliche Straßen,* H ViSt).

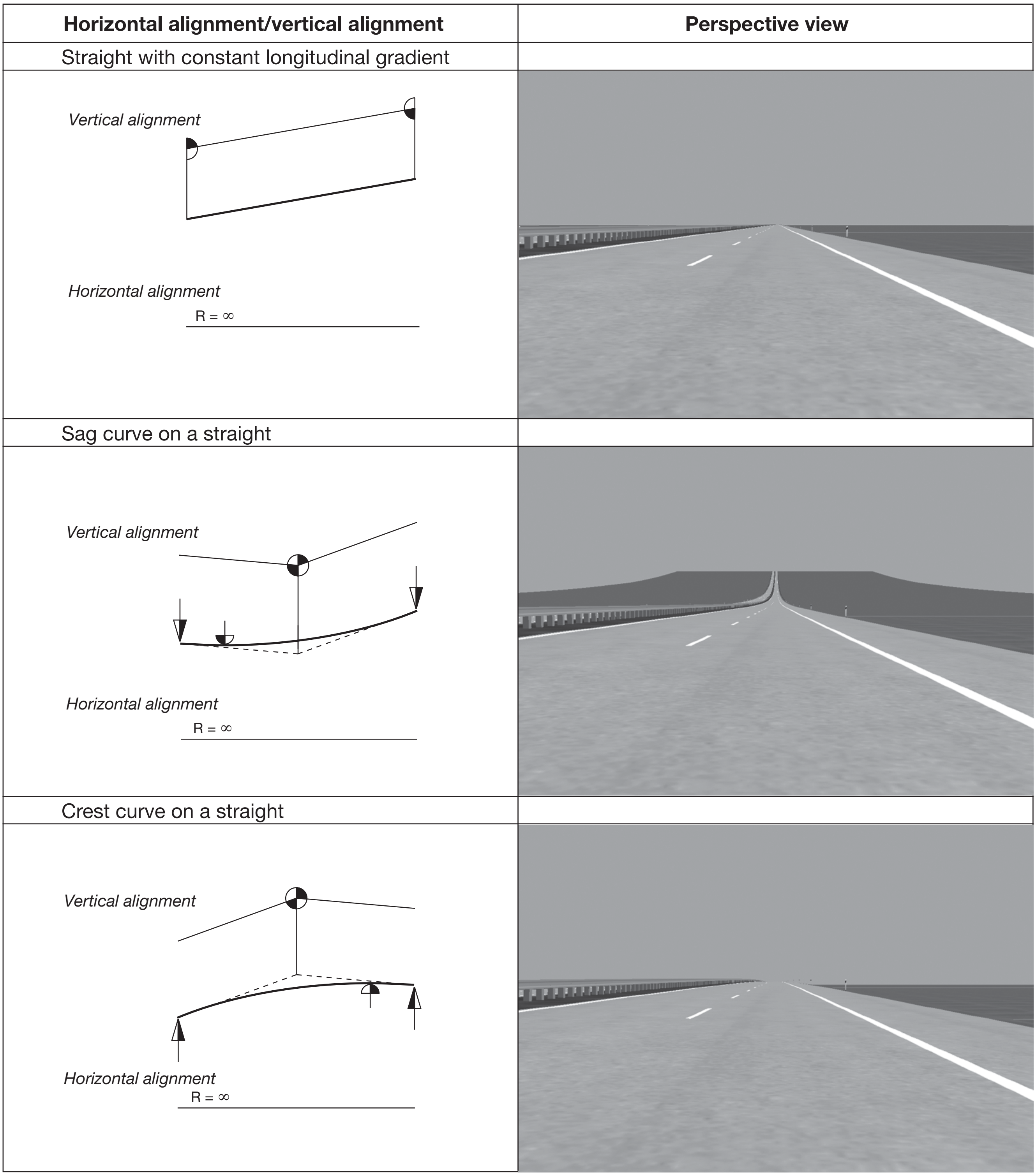
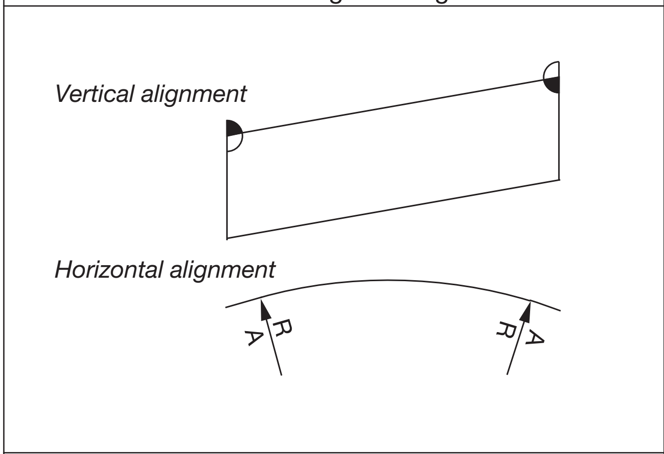


Fig. 13: Spatial elements of horizontal straights (superimposition of horizontal alignment and vertical alignment design elements and including cross-sections)

5.4.2 Designing the roadway

Good road alignment has a positive effect on driver behaviour and road safety. It can be achieved by ensuring a harmonious succession of elements. At the same time, drivers should be able to see sufficiently far ahead along the road, allowing them to recognize and appreciate the direction of the road for some distance ahead.

Basically, optical distortions on motorways and road safety deficiencies resulting from the incorrect superimposition of horizontal and vertical elements can be avoided by observing the minimum values for design elements (Sections 5.2 and 5.3).

<table>
<tr><th>Horizontal alignment/vertical alignment</th><th>Perspective view</th></tr>
<tr><td>Curve with constant longitudinal gradient</td><td></td></tr>
<tr><td>


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<tr><td>Sag in a curve</td><td></td></tr>
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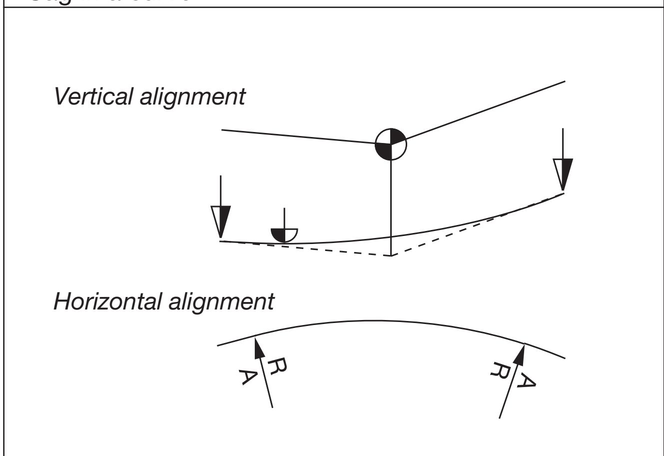

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<tr><td>Crest in a curve</td><td></td></tr>
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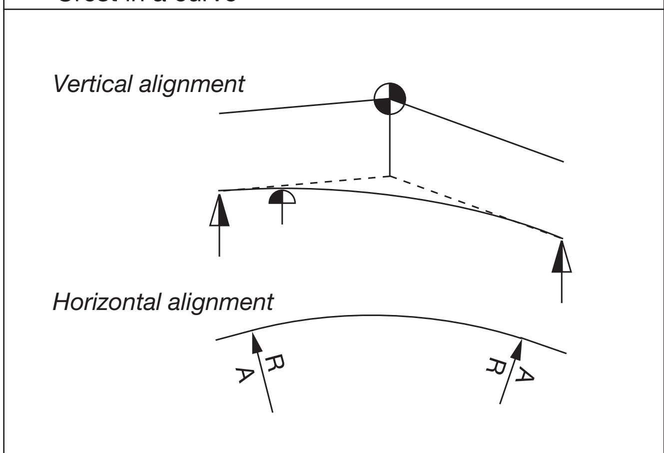

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</table>

Fig. 14: Spatial elements of horizontal curves (superimposition of horizontal alignment and vertical alignment design elements and including cross-sections)

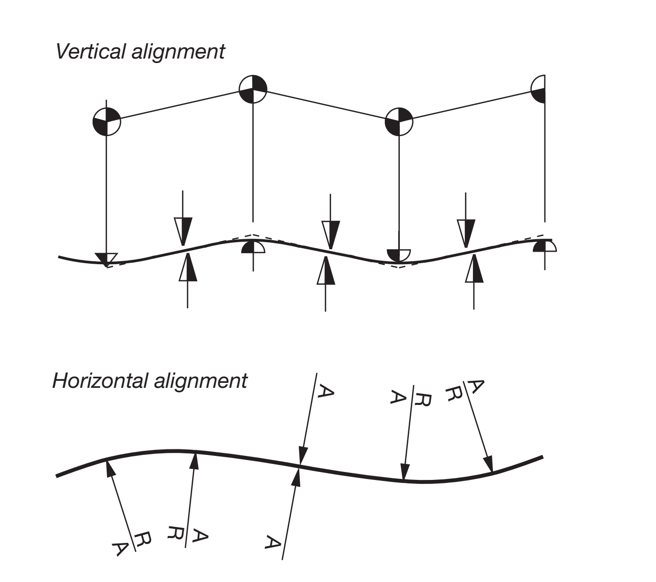
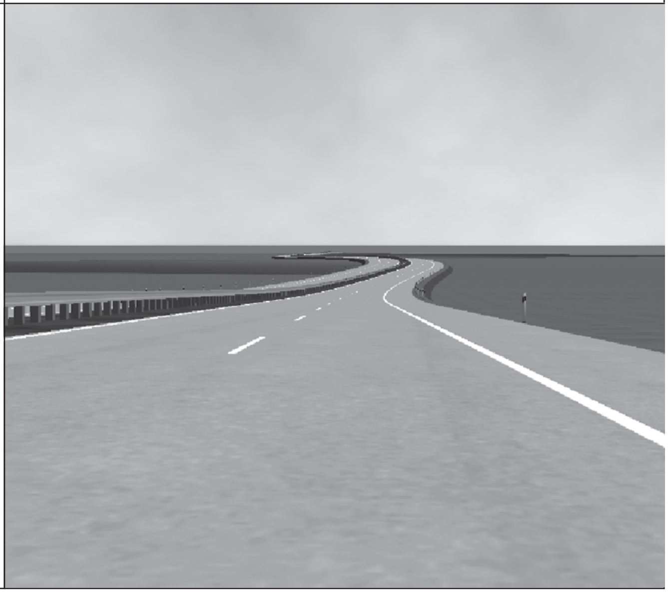
Horizontal alignment/vertical alignment	Perspective view
	

Fig. 15: Typical alignment and perspective view

The alignment may generally be considered satisfactory both in terms of optics and drainage when the points of curvature of the curves are at approximately the same place in the horizontal and vertical alignment (Fig. 15). This is based on the assumption that there are the same number of points of curvature in the horizontal and vertical alignment.

If it is not possible to avoid having a different number of points of curvature, steps should be taken to make sure that the points of curvature in one plane (horizontal or vertical) do not coincide with the points of intersection in the other plane. The alignment is also more pleasing when the points of intersection of the horizontal and vertical curves are as close together as possible and surplus points are positioned in between them, even if there is a different number of points of curvature.

In order to ensure that the course of the road is aesthetically pleasing and relaxing for the driver, a number of basic rules should be observed for successions of spatial elements.

- The visual impact of the road is improved by making the following elements much larger than stipulated by the minimum values:
- the radius of circular curves,
- the length of circular curves,
- the diameter of crests and sags,
- the tangent length of crest curves and sag curves.

The instructions in Section 5.2.1 apply when designing straights in the horizontal alignment. Tight circular curves with small angles of direction change in particular appear as sharp bends from the drivers' perspective. The only way to avoid this effect is to increase the radius of the circular curve (Fig. 16).

In terms of vertical alignment, short sags between long horizontal straights with a constant longitudinal gradient should be avoided because they can also appear as a sharp dip to drivers (Fig. 16).

Conversely, short straights between two successive sags should be avoided, at least on steep longitudinal gradients, because they can appear to drivers as either a 'flat, straight board' section or even a crest (Fig. 17).

The tangent length in the vertical alignment should be approximately equal to that for the horizontal alignment elements in order to avoid the impression of sharp dips and bends at crests and sags along gradual longitudinal gradients.

The succession of elements in the vertical alignment should follow the shape dictated by the terrain as much as possible. In hilly terrain, the diameter of the crest should, as a rule, be greater than the diameter of the sag. On the other hand, in the case of minor differences in height and in flat terrain, significantly larger sag diameters should be chosen to achieve an optically pleasing line.

If the alignment adheres too closely to undulations in the terrain, the carriageway may seem to 'flutter' or be discontinuous (Fig. 18).

Bridges should be integrated into the course of the road. The 'flat, straight board' effect created by a straight bridge between two sags should be avoided. In such cases, the diameter of the sag should be particularly large and its length should be long (see also Fig. 17).

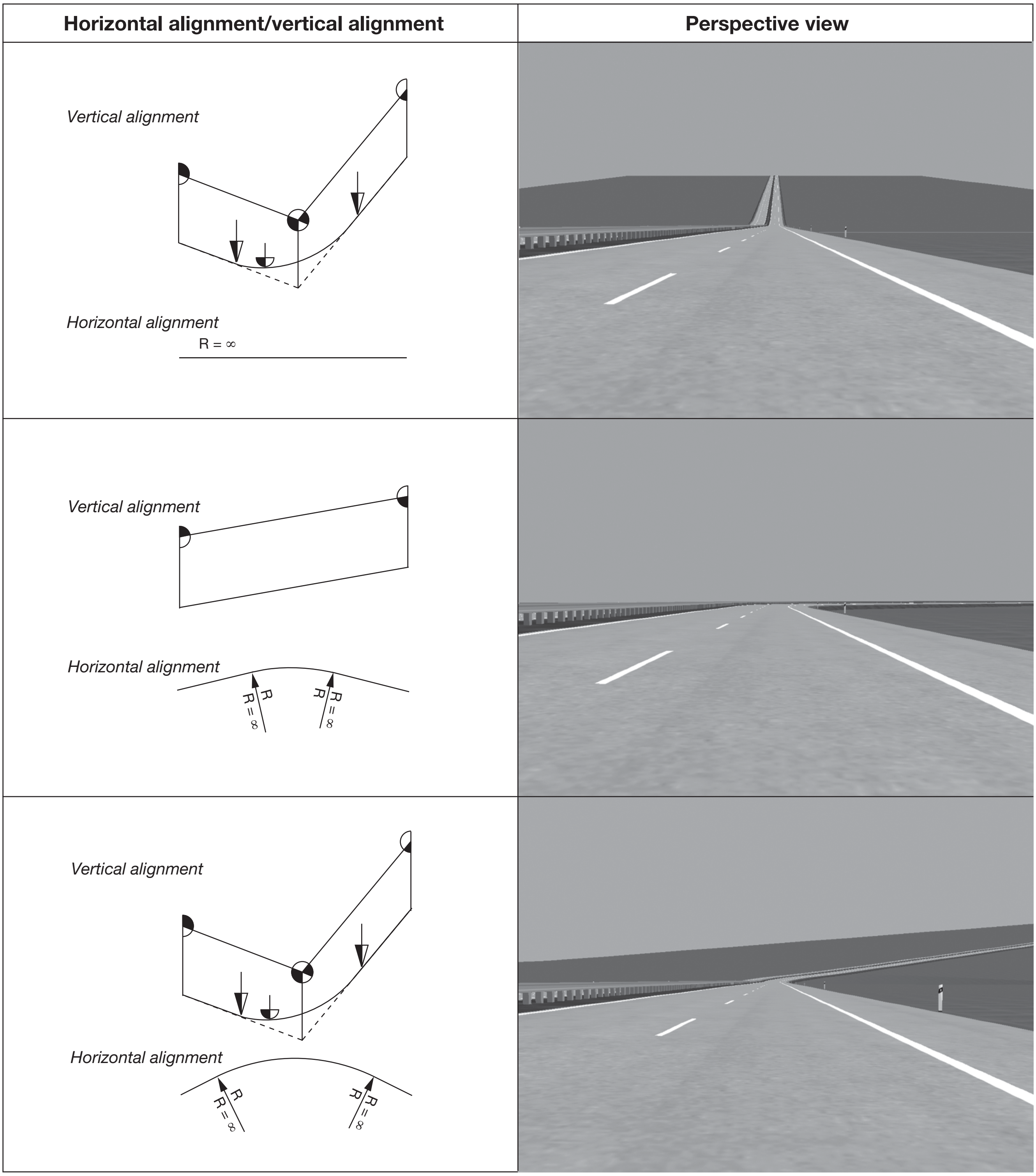


Fig. 16: Apparent sharp bends and sharp dips, which should be avoided

Horizontal alignment/vertical alignment	Perspective view

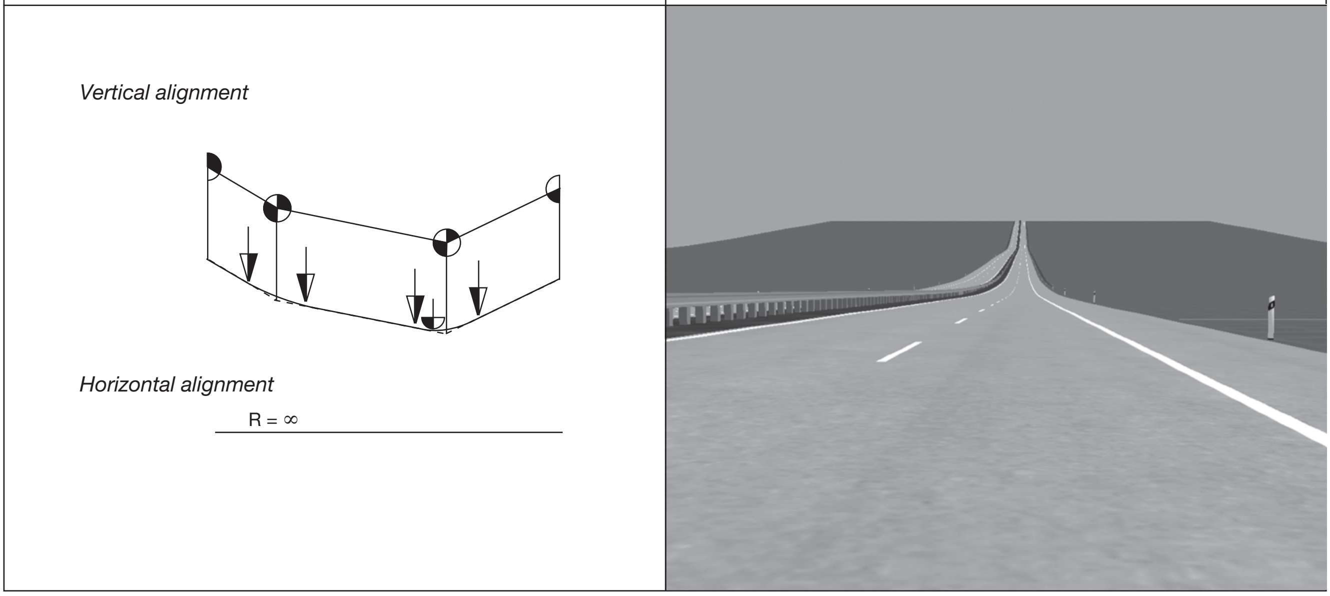


Fig. 17: Perspective of a road section of an unusual vertical alignment with a short straight that creates the appearance of a 'flat, straight board' road section, which should be avoided

Horizontal alignment/vertical alignment	Perspective view

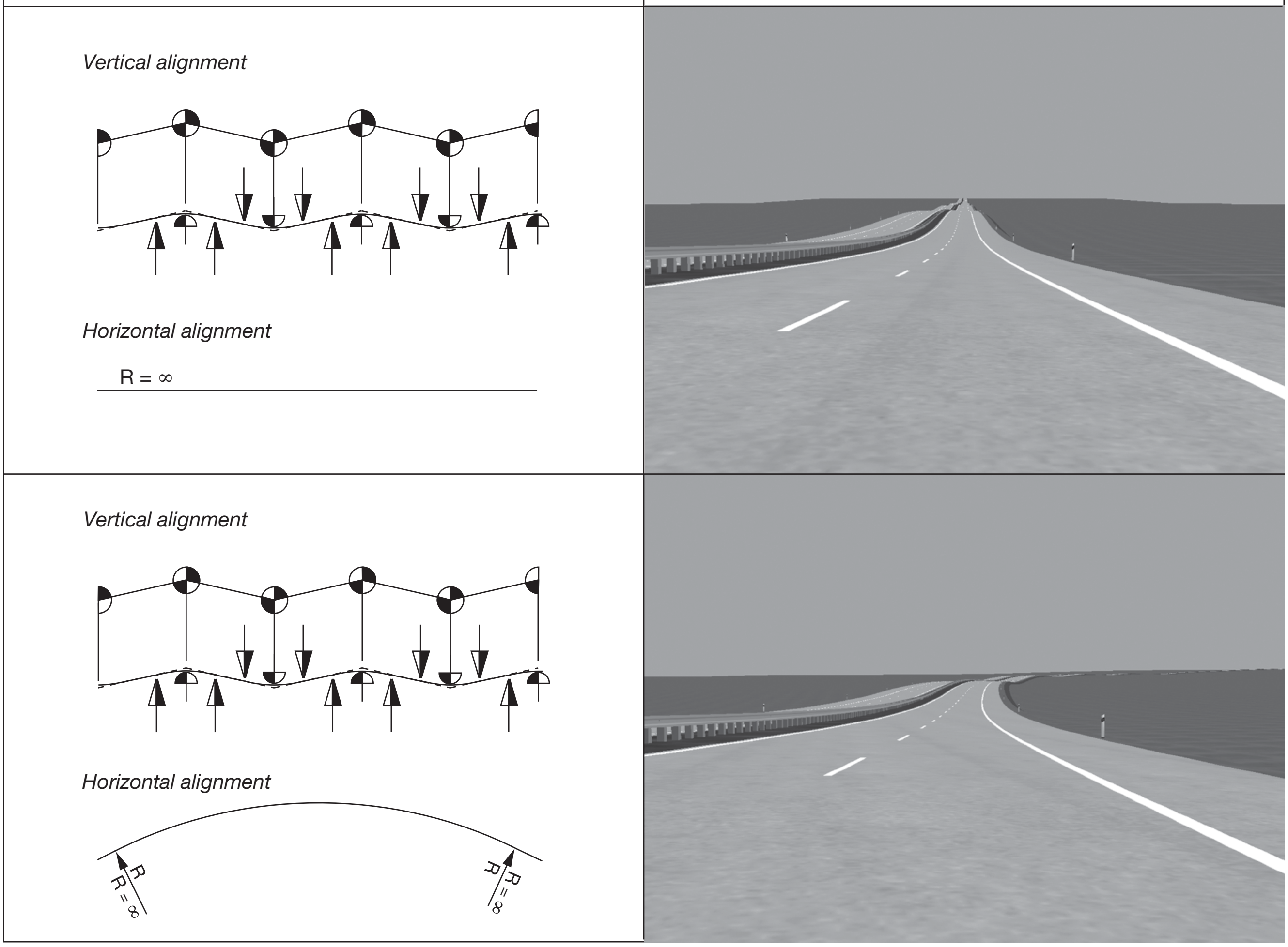


Fig. 18: A road that appears to 'flutter' on the straight and in the curve, which should be avoided

5.5 Stopping sight distance

5.5.1 General remarks

For reasons of road safety and traffic flow quality, it is essential that the stopping sight distance be met. The purpose of doing so is to give the driver enough time to stop before a hazard. Moreover, it is a requirement in road design that ensures that drivers have enough time to gather information, respond, and stop.

5.5.2 Minimum stopping sight distance

The minimum stopping sight distance (erf Sh) is the distance a driver needs to stop before an unexpected obstruction (e.g. the back of a queue) in wet conditions. It is determined from the distance travelled during the driver's reaction time and the vehicle's response time and the braking distance. In this regard, the special conditions surrounding driver behaviour on motorways are considered. This is why the values for stopping sight distance are greater than the physiologically determined minimum values for the reaction time and the possible braking distances determined by the dynamics of vehicle movement.

The minimum stopping sight distance varies depending on the speed and the longitudinal gradient (Fig. 19, Table 33 in Appendix 7). If no binding speed limit has been included in the plan, the minimum stopping sight distance for the recommended speed, V, of 130 km/h must be used.

5.5.3 Available sight distance

The available sight distance is determined by the horizontal and vertical alignment, the cross-section, and the presence of visual obstructions in the vicinity of the road. It is depicted as a line of sight between the driver's eye point and an object point (ZP). Both the driver's eye height and the object height are 1.0 m. The object height is based on the ability of a driver to recognize a vehicle at the back of a queue (Appendix 6).

The driver's eye height and the object height are both measured in the same lane (Fig. 20). For motorways, the following assumptions apply:

– in left-hand curves, the driver's eye point and the object point are on the lane that is farthest to the left on each carriageway.
– in right-hand curves and on straights, the driver's eye and object point are on the lane that is farthest to the right on each carriageway.

The curve radius and the distance between the visual obstruction and the centreline of the chosen lane significantly limit the sight distance in left-hand curves. This distance is influenced by the design of the cross-section (including lane width, central reserve width, and the width of the obstruction).

For an approximate check of the stopping sight distance in left-hand curves, the links between the radius of the circular curve in the horizontal plane and the available sight distance are demonstrated in Fig. 21. To simplify things, the distance of the driver's eye point from the

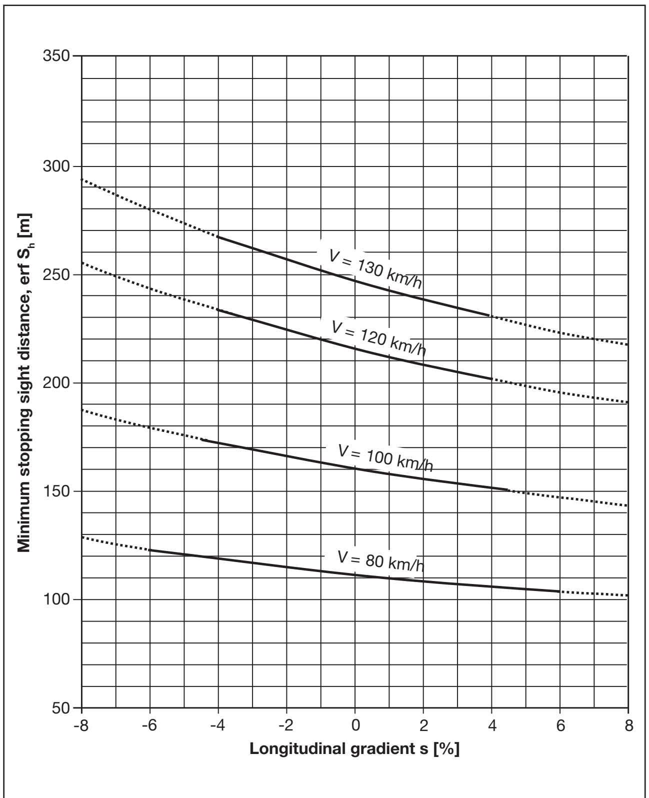


Fig. 19: Minimum stopping sight distance, erf S_h

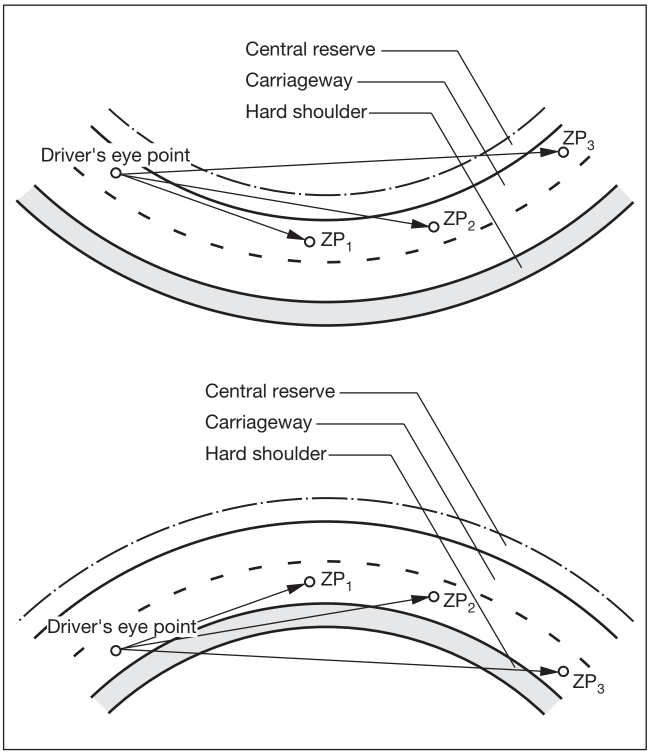


Fig. 20: Possible line of sight from the driver's eye point to the object point for the stopping sight distance in left-hand and right-hand curves

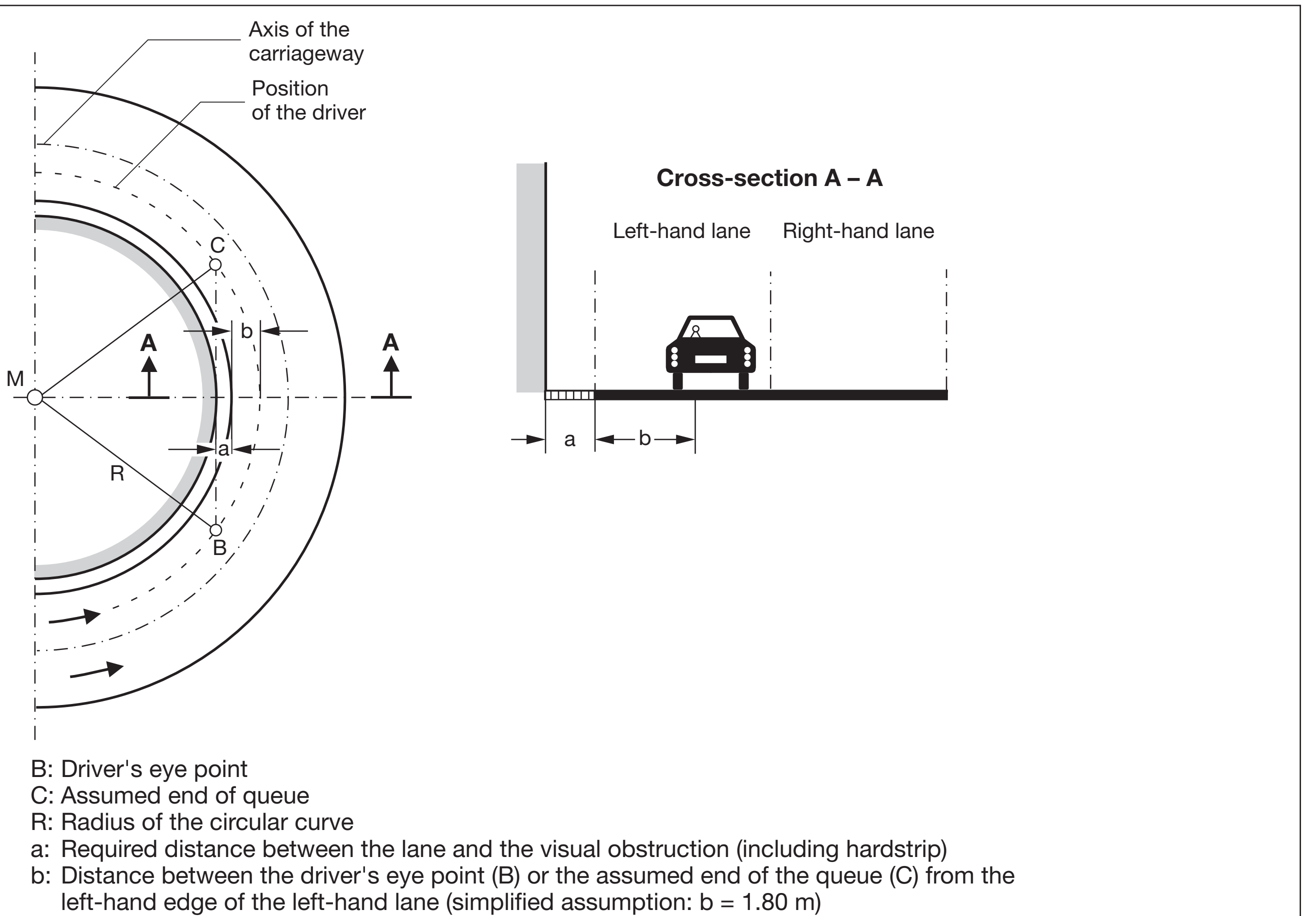


Fig. 21: Geometric model for calculating the available sight distances on carriageways in left-hand curves

edge of the left-hand lane is assumed to be 1.80 m so that the various lane widths can be adequately taken into account in accordance with Section 4.2.3.2.

5.5.4 Checking the sight distance

Station by station, the available sight distances shall be compared with the minimum stopping sight distance using sight distance chords, one for each direction.

The purpose of doing so is to check that the available sight distance is equal to or greater than the stopping sight distance, or

$$\text{vorh } S \geq \text{erf } S_h \qquad (9)$$

has been met at every station on the curve for the most unfavourable lane on each carriageway.

All obstructions to sight lines (e.g. by slopes planted with grass or shrubs, noise barriers, and protective devices, especially around slip roads) must be avoided up to the height of the line of sight in the field of vision that must be kept free along the carriageway. This applies, in particular, to plant cover in the central reserve (Section 7.7).

For radii around the limiting values, the minimum stopping sight distance on the left-hand lane of the carriageway can only be met if there is no plant cover (vegetation) and no vehicle restraint systems (safety barriers) above a height of 0.90 m in the central reserve. Otherwise, it will be necessary to revise the plans or, in the case of roads that are being reconstructed or improved, to introduce a speed limit (generally only for wet conditions). Therefore, whether a vehicle restraint device in the central reserve constitutes a visual obstruction depends on the geometry of the road.

Fig. 22 gives an indication of the distance that must be maintained between passive protective devices or plant cover in the central reserve and the edge of the carriageway.

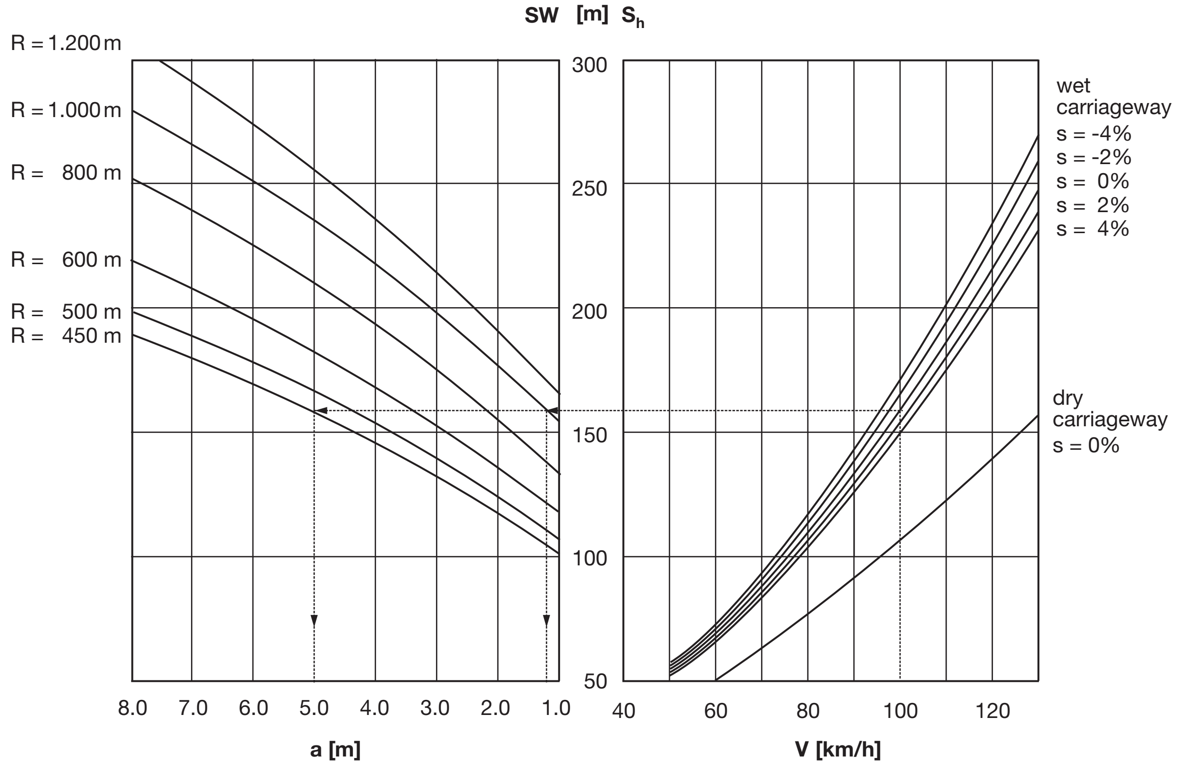


Fig. 22: Minimum stopping sight distance and distances that must be maintained between the left-hand edge of the inside lane of a carriageway and visual obstructions in the central reserve

5.6 Roadway surface

5.6.1 Crossfall on straights

On straights, carriageways are designed with a one-sided crossfall, q, of at least 2.5 % to the outside.

Depending on direction and size, additional lanes, merging and diverging lanes, and hard shoulders should have the same crossfall as the carriageway.

Verges that are used for carriageway drainage have a crossfall, q, of 12.0 %. Verges that are not used for draining the carriageway have a crossfall of 6.0 %.

5.6.2 Crossfall in circular curves

For reasons of vehicle dynamics, circular curves are generally established with a crossfall towards the inside of the circular curve ('positive crossfall'). The minimum crossfall is

$$\min q = 2.5\,\% \qquad (10)$$

The maximum crossfall is limited to

$$\max q = 6.0\,\% \qquad (11)$$

In exceptional cases, e.g. when the radius is smaller than the minimum radius, the crossfall can be increased to 7.0 %.

The maximum incline, p, of 9.0 %, which is the line of maximum slope resulting from the longitudinal gradient and crossfall, must be observed to avoid vehicles sliding off the road in icy conditions.

Fig. 23. illustrates the relationship between radius and crossfall. These values should be rounded up to the nearest 0.5 %.

The crossfall on bridges should be restricted to

$$\max q = 5.0\,\% \qquad (12)$$

(Section 8.4).

In order to avoid superelevation development sections where the crossfall passes through zero, a crossfall, q, of -2.5 % to the outside of the curve ('negative crossfall') is permissible for circular curves. In this case, a speed limit for wet conditions will be necessary and must be applied (Table 17).

Table 17: Minimum radii for the design of crossfalls in the direction of the outside of the curve

Design class	**min R** [m]	**Speed limit in the wet V_{nass}** [km/h]
EKA 1 A	4,000	–
EKA 1 B	3,200	120
EKA 2	1,900	100
EKA 3	1,050	80

The direction of the crossfall may not change for a succession of curves that curve in the same direction.

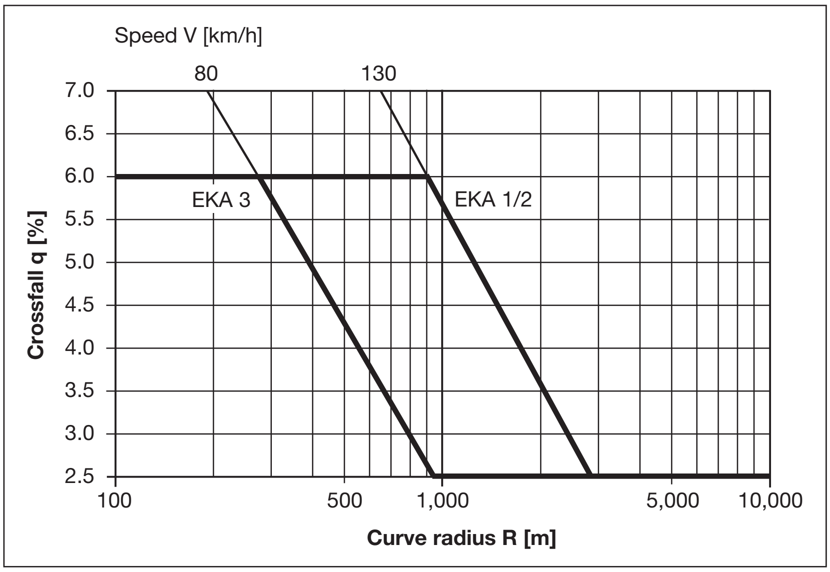


Fig. 23: Crossfalls based on the design class and the radius of the curve
(max q = 6.0 %, exception: q = 7.0 %)

A crown in the cross-section is permissible at the end of a diverging lane between the through carriageway and the diverging lane if it would not otherwise be possible to achieve the superelevation and the pavement rotation in the transition curve. The difference between the crossfalls on the mainline carriageway and the diverging lane may not, however, exceed 5 % at the tip of the painted (ghost) island. The superelevation development section may, if necessary, be extended so far into the diverging lane that a crossfall, q, of 0 % is achieved at the start of the transition curve in the diverging lane.

These instructions apply accordingly to merging lanes.

5.6.3 Superelevation and superelevation development

5.6.3.1 Application

The crossfall of a carriageway is changed over a section of the road known as the superelevation development section. Over the length of this section, the edges of the carriageway are superelevated and the roadway is rotated about a certain ‘axis of rotation’. The superelevation development (or rotation of the pavement) generally takes place within the transition curve, regardless of the axis around which the roadway is rotated. All paved strips alongside the carriageway are also rotated in the transition curve or the relevant transition section.

If, in exceptional cases, there is no transition curve, the superelevation is developed as follows: on stretches where a straight is followed by a circular curve, half of the superelevation is developed before the point where the two elements meet and the other half after that point.

On motorways, the crossfall is generally changed by rotating the pavement around the axes of the carriageways (fig. 24, case 1).

In special cases – e.g. around central reserve crossing points, tunnels, and in cases where visibility is reduced at central reserves – carriageways can be rotated around the edges of the carriageway at the central reserve or around the road centre line (Fig. 24, cases 2 and 3).

5.6.3.2 Limiting values

The relative grade Δs [%] is the difference between the longitudinal gradient along the edge of the carriageway and the longitudinal gradient along axis of rotation. It is calculated as follows:

$$\Delta s = \frac{q_e - q_a}{L_v} \cdot a \qquad (13)$$

where

q_e [%] = crossfall of the carriageway at the end of the superelevation development section

q_a [%] = crossfall of the carriageway at the start of the superelevation development section (q_a should be negative if in opposite direction to q_e)

L_v [m] = superelevation development length

a [m] = distance between the edge of the carriageway and the axis of rotation

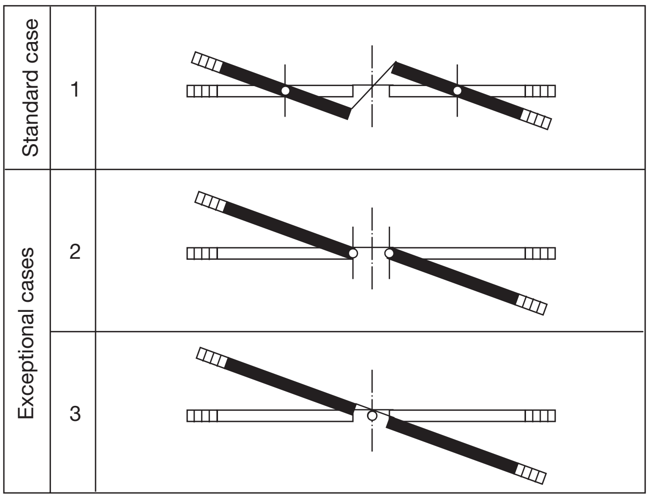


Fig. 24: Axes of rotation of the carriageway on superelevation development sections

In order to avoid a rapid increase in the crossfall within the superelevation development section, the maximum relative grade (max Δs) should not exceed the values given in Table 18.

Table 18: Limiting values for the relative grade

Design class	**min Δs [%]** at q ≤ 2.5 %	**max Δs [%]** at a < 4.00 m	**max Δs [%]** at a ≥ 4.00 m
EKA1, EKA 2	0.10 · a	0.225 · a	0.9
EKA 3		0.25 · a	1.0
a [m]: Distance between the edge of the carriageway and the axis of rotation, max Δs ≥ min Δs			

The minimum superelevation development length is calculated as follows:

$$\min L_v = \frac{q_e - q_a}{\max \Delta s} \cdot a \qquad (14)$$

where

max Δs [%] = maximum relative grade

q_e [%] = crossfall of the carriageway at the end of the superelevation development section

q_a [%] = crossfall of the carriageway at the start of the superelevation development section (qa should be negative if in opposite direction to qe)

min L_V [m] = minimum superelevation development length

a [m] = distance between the edge of the carriageway and the axis of rotation

The basic forms of superelevation development sections are illustrated in Fig 25a and Fig 25b.

5.6.3.3 Drainage considerations

In order to minimize zones with poor drainage, the relative grade in superelevation development sections may not fall below the minimum relative grade (min Δs) in Table 18 in the area from +min q (+2.5 %) through 0 % to -min q (-2.5 %).

If on a continuous superelevation development section, the available relative grade is less than the minimum relative grade (avail Δs < min Δs), it will be necessary to divide the superelevation development. In this case, the area where the crossfall passes through zero between +2.5 % and -2.5 % shall have a relative grade of min Δs. The remaining superelevation is applied on the remaining section of the transition curve until the crossfall required for the circular curve is achieved, having regard to the minimum relative grade (Δs < min Δs).

Moreover, the longitudinal gradient and the minimum relative grade should be co-ordinated in order to guarantee adequate drainage. To this end, designers should aim for a difference of 0.2 % between the longitudinal gradient and the relative grade.

Neither of the two carriageway edges may have a slope opposite to the gradient.

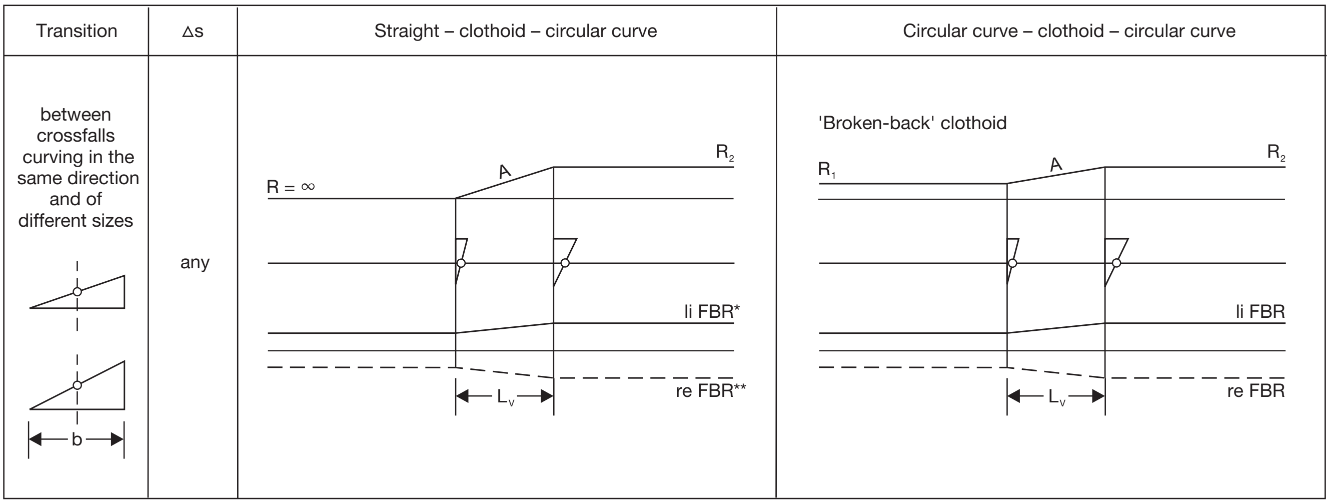
The following conditions must be met for the longitudinal gradient of the centre and both edges of the carriageway:

$$s_{\text{Centre of carriageway}} \geq 1.0\,\% \text{ (exception: 0.7 \%)} \qquad (15)$$

$$s_{\text{Edge of carriageway}} \geq 0.5\,\% \text{ (exception: 0.2 \%)} \qquad (16)$$

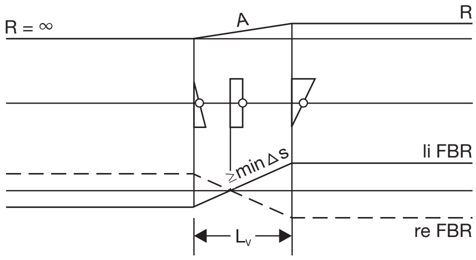
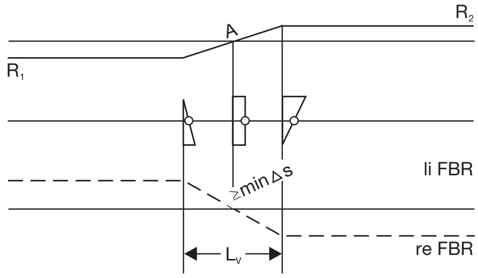
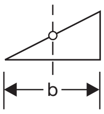
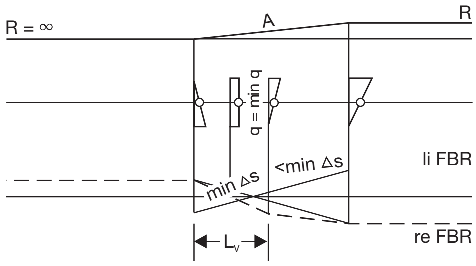
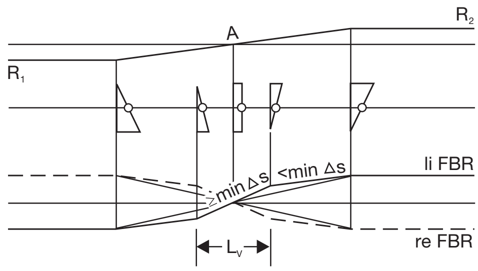
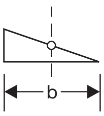
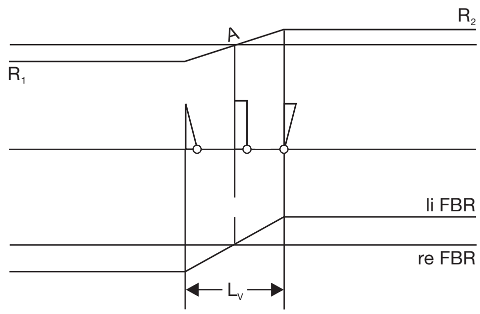
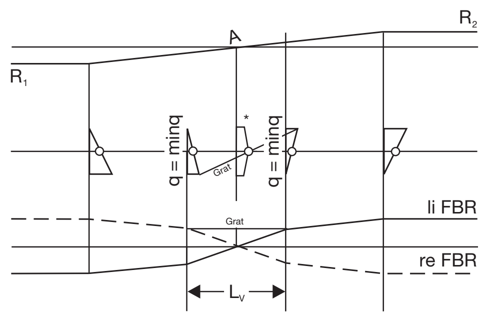
The requirement of a minimum incline of p = 0.5 % as stipulated in the Guidelines for the Design of Highways: Drainage *(Richtlinien für die Anlage von Straßen Teil: Entwässerung*, RAS-Ew*)* can, however, result in greater values.

If it is not possible to achieve sufficient longitudinal gradient because of specific constraints around the clothoid point of curvature, the origin of the crossfall compared with the clothoid point of curvature can be moved by the distance, L, equal to 0.1 × A. The same applies to a straight followed by a clothoid followed by a circular curve.



○ Axis of rotation * Left edge of carriageway ** Right edge of carriageway

Fig. 25a: Forms of superelevation development sections

Transition	Δs	Straight – clothoid – circular curve	Circular curve – clothoid – circular curve
between crossfalls of the same or different size curving in the opposite direction	≥ min Δs		Reverse clothoid 
	< min Δs		
	≥ min Δs		Rotation around a carriageway edge 
	< min Δs		Inclined superelevation 

o Axis of rotation

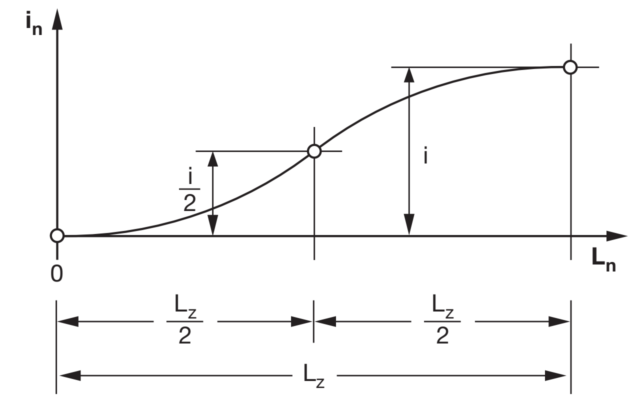
* In the area around the inclined superelevation, the axis of rotation submerges into the road and runs straight through.

Fig. 25b: Forms of superelevation development sections

In the case of six- or eight-lane standard cross-sections, the depth of the water film can, in certain circumstances, be higher than the critical measure of 2 mm. In such cases, the following options can be considered:

- an increase of the longitudinal gradient (for short sections or flow paths);
- the use of porous wearing courses;
- structural drainage measures
- avoidance of superelevation development sections by using a negative crossfall in the case of radii in accordance with Table 17; or
- the avoidance of zones with poor drainage by establishing an inclined superelevation during improvement projects (should be avoided on new build projects as it is disadvantageous in terms of vehicle dynamics and very difficult to achieve a structurally permanent solution).

Whether one of these measures is necessary shall be based on a detailed calculation to provide the relationship between water film depth, speed, and risk of aquaplaning. If so, the most suitable measure will be chosen on the basis of the specific planning conditions.



$$i_n = \frac{2 \cdot i \cdot L_n^2}{L_z^2} \quad \text{für } 0 \leq L_n \leq \frac{L_z}{2}$$

$$i_n = i - \frac{2 \cdot i \cdot (L_z - L_n)^2}{L_z^2} \quad \text{für } \frac{L_z}{2} \leq L_n \leq L_z$$

i	[m]	Widening of the carriageway
L_z	[m]	Length of the taper
i_n	[m]	Widening of the carriageway at the point under consideration
L_n	[m]	Length of the taper at the point under consideration

Fig. 26: Tapering of the edges of the carriageway in the case of two quadratic parabolic curves without a straight in between

If none of the above-mentioned measures can be implemented, the designers should consult with the traffic authorities about the introduction of a speed limit.

5.6.4 Widening carriageways

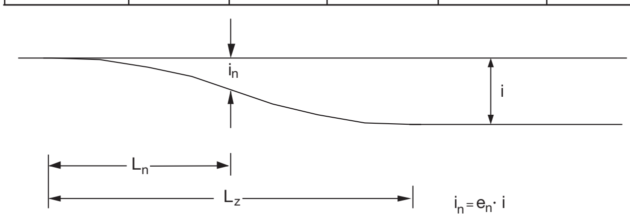
- Widening of the carriageway with tapering of the edges of the carriageway will be necessary when
- changing the cross-section of the carriageway (e.g. ahead of bridges or tunnels);
- constructing an additional lane (Section 8.1, Fig. 66); or
- when constructing a diverging or a merging lane (Section 6.4.3, Table 22, and Section 6.4.4, Table 24).

Depending on the application at hand, the widening of the carriageway around a curve should be established asymmetrically on the inside edge of the curve while the widening of the carriageway around an extended alignment should be established symmetrically on both sides of the road centre line to ensure a visually pleasing alignment of the through lanes.

The edges of the carriageway shall, where possible, be aligned independently of the road centre line or shall be tapered as two quadratic parabolic curves that are combined to form an S curve (Fig. 26 and Table 19).

Table 19: Uniform tapering for carriageway widening using two quadratic parabolic curves

$a = \frac{L_n}{L_z}$	e_n	Δe_n	$a = \frac{L_n}{L_z}$	e_n	Δe_n
0.00	0.000	0.005	0.50	0.500	0.095
0.05	0.005	0.015	0.55	0.595	0.085
0.10	0.020	0.025	0.60	0.680	0.075
0.15	0.045	0.035	0.65	0.755	0.065
0.20	0.080	0.045	0.70	0.820	0.055
0.25	0.125	0.055	0.75	0.875	0.045
0.30	0.180	0.065	0.80	0.920	0.035
0.35	0.245	0.075	0.85	0.955	0.025
0.40	0.320	0.085	0.90	0.980	0.015
0.45	0.405	0.095	0.95	0.995	0.005
0.50	0.500		1.00	1.000	



6 Junctions and interchanges

6.1 General remarks

Motorway junctions are grade-separated. Depending on the classification of the roads being connected to the motorway, these junctions can be either grade-separated or partially grade-separated.

Four-way interchanges (*Autobahnkreuze*) and three-way interchanges (*Autobahndreiecke*) are grade-separated intersections that connect motorways with each other. They can, however, be used to connect motorways and rural roads belonging to the rural road design class EKL 1 in accordance with the RAL.

Motorway junctions (*Anschlussstellen*) are generally partially grade-separated and are used to connect motorways with roads belonging to the subsidiary road network (rural roads, urban streets). Subsidiary network roads are connected to slip roads at grade. Grade-separated intersections can also be used to ensure capacity at peak traffic times.

A number of different junction systems (Section 6.3) can be used for junction design. These systems comprise several junction elements (Section 6.4, Appendix 8). In addition to the mainline carriageway, a differentiation is made between road elements (slip roads) and connector elements (exits, entries). An intermediate category of junction element is the weaving area, which comprises a road element (part of the slip road) and two connector elements (entry with lane gain at the start and exit with lane drop at the end).

This section of the RAA deals with all systems relating to grade-separated and partially grade-separated motorway junctions and all grade-separated elements at these junctions. For standard solutions relating to grade-separated or partially grade-separated junctions on rural roads, please refer to the RAL.

6.2 Planning for junctions

6.2.1 Junction requirements

In order to ensure traffic safety at junctions, it is important to give drivers clear directions and in sufficient time so that they can drive appropriately. To this end, junctions shall be designed in such a way that they allow drivers to continuously adjust their behaviour, adapt to the changing road characteristics, and reduce speed as necessary. To this end, the separating and connecting elements of the junction elements should be identifiable in sufficient time.

- Moreover, the junction elements should be
- indicated well in advance on direction signs,
- clear and easy to understand,
- safe to drive on, and
- ensure adequate capacity.

6.2.2 Junction spacing

The location of motorway junctions is determined by the network plan and considers the network hierarchy of road categories and spatial conditions (urban structure, topography). To assist in network planning, designers shall endeavour to observe the following minimum (axis)

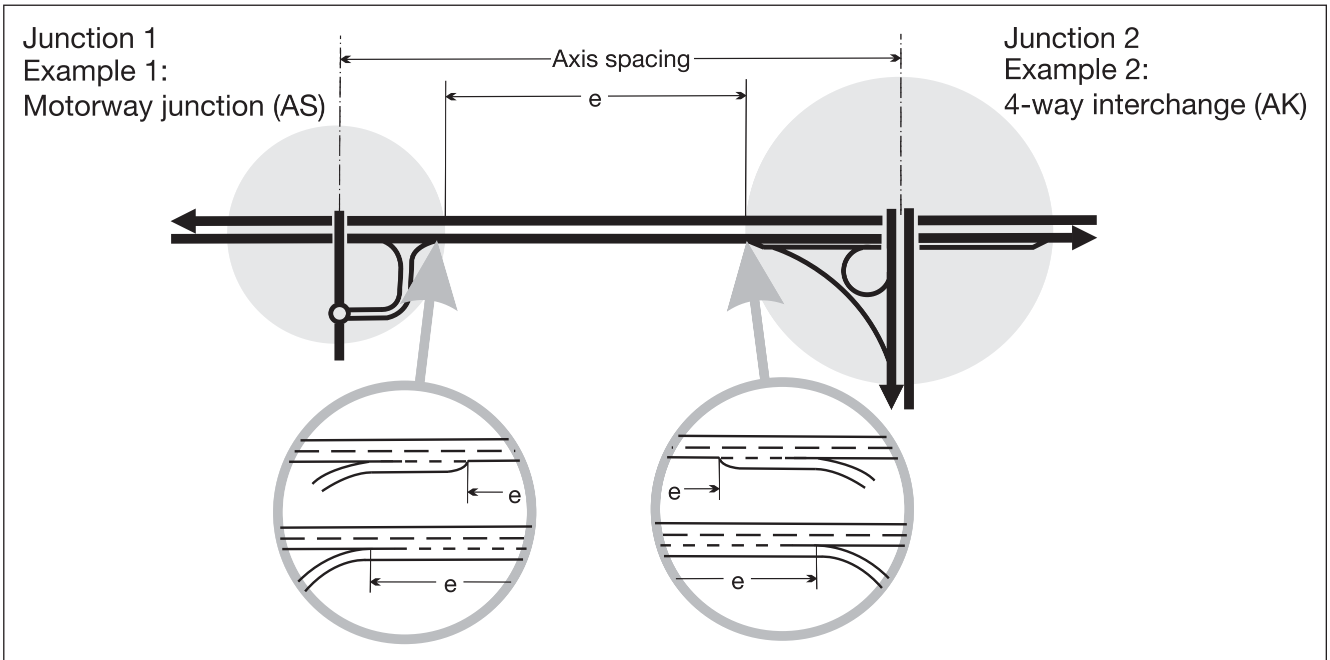


Fig. 27: Axis spacing and actual junction spacing (e)

Table 20: Minimum values for the actual junction spacing (e)

Type of junction downstream	Minimum value for standard direction signing	Minimum value for individual direction signs in special cases in accordance with the RWBA*)	Minimum value for isolated junction planning
Four-way/three-way interchange	3,000 m	1,600 m	600 m
Motorway junction	2,000 m	1,100 m	600 m

*) Important only in the case of more than two junctions in close succession

spacing between two consecutive junctions outside built-up areas:

– 8.0 km for EKA 1 A motorways and

– 5.0 km for EKA 1 B and EKA 2 motorways.

More closely spaced junctions also make good planning sense for EKA 3 motorways for an urban motorway to fulfil the collector and distributor function.

These intervals ensure there is a sufficiently long section between the sign indicating distances after the first junction (KP 1) and the first advance direction sign ahead of the next junction (KP 2). This section allows drivers to have a period of relaxed driving and allows the traffic flow to settle down without being disturbed by a junction.

The same principles apply to the spacing of motorway services areas (see Section 8.6) and junctions.

In densely built-up areas – and also outside them in cases where there are specific constraints – it may not be possible to observe the stipulated spacing. In these cases, the minimum spacing derived from the spacing requirements for directional signing must be observed.

The **actual junction spacing (e)** between the end of the last entry taper at junction 1 and the start of the first exit taper at junction 2 (Fig. 27) is an important factor. This approximately equals the reference value for the spacing in accordance with the Guidelines for Directional Signing on Motorways *(Richtlinien für die wegweisende Beschilderung auf Autobahnen,* RWBA*)*. In the case of lane gain and lane drop associated with weaving lanes, it corresponds to the distance between the noses of the islands.

The actual junction spacing is calculated on the basis of the junction system in question and a preliminary estimate regarding the geometry of the slip road.

In the case of two consecutive junctions, remedial measures a) and b) in Fig. 28 can be used to maximize the actual junction spacing if the axis spacing allows. The prerequisite for this is that two full junctions are replaced by two partial junctions, which is only possible if the excluded traffic movements can be absorbed by the subsidiary road network.

The actual junction spacing should not fall below the minimum values given in Table 20 in order to allow for standard signing in accordance with the RWBA.

The RWBA provide special signing solutions for actual junction spacings between two junctions that are smaller than those given in Table 20. These solutions involve dispensing with individual signs for each exit and, where necessary, indicating two closely spaced exits on the same sign. In cases where there are more than two junctions in close succession, the exceptional values (in accordance with RWBA) must be used because the overlapping of directional signing stipulated by the RWBA for spacings that are closer than the minimum may only be applied to two consecutive junctions (*Verkettungsverbot*).

If the actual junction spacing falls below the minimum values given in Table 20 for an isolated junction plan, the junctions influence each other both in terms of structural design and traffic engineering as well as in terms of traffic flow. In this case, the junctions can no longer be planned as isolated systems that function independently and do not influence one another.

In this case, both junctions must be merged using either weaving lanes (solution c in Fig. 28) or link roads (solution d in Fig. 28) to create a complex junction. The absolute minimum value for the actual junction spacing here is the result of the minimum length of the weaving section on the mainline carriageway (solution c) or on the link road (solution d) in accordance with Section 6.4.5. However, in the case of the weaving lane on the mainline carriageway, a special solution for directional signing in accordance with the RWBA that is restricted to two consecutive junctions is necessary.

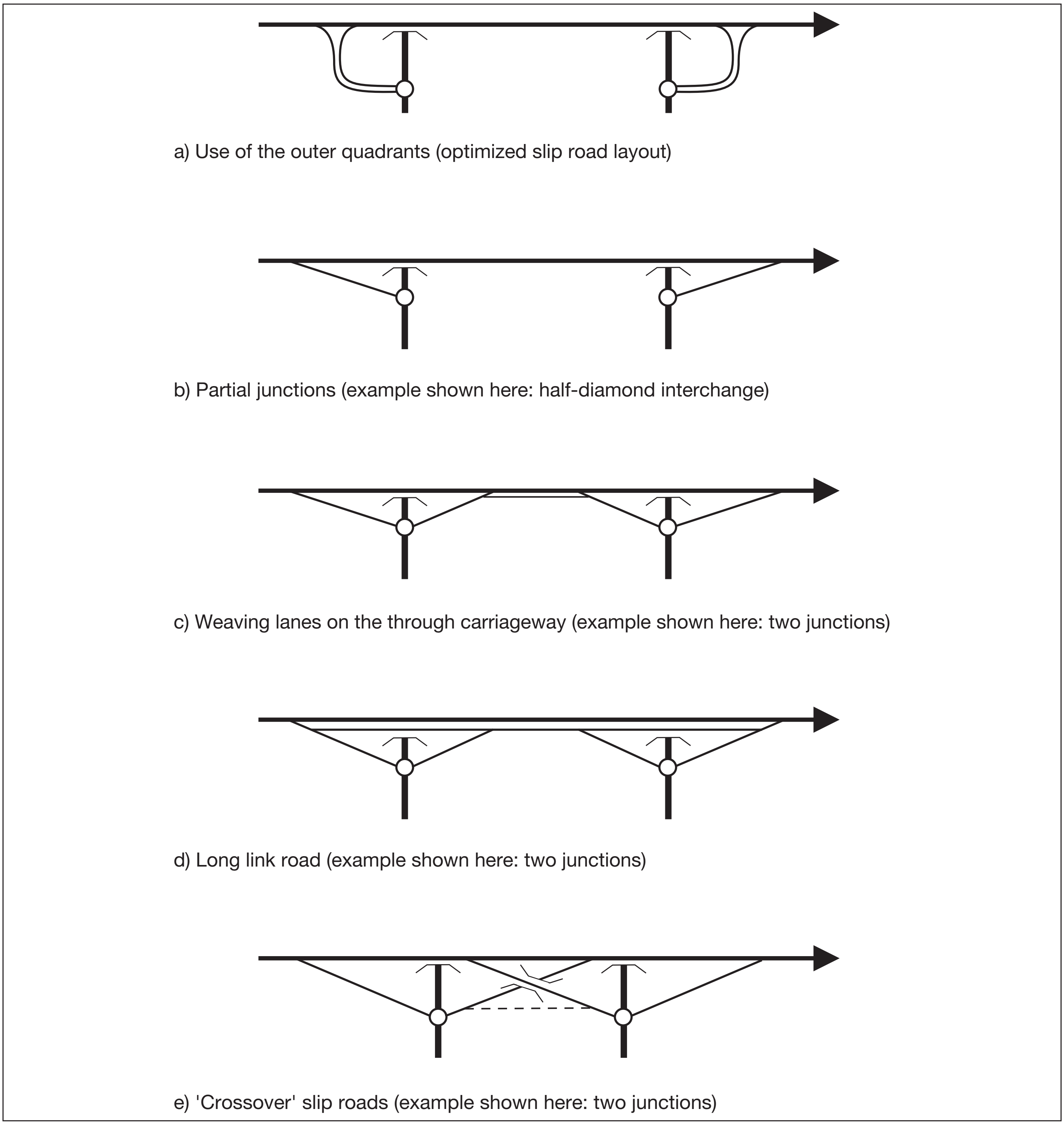
If there are more than two junctions in close succession and if the minimum values stipulated by the RWBA in accordance with Table 20 are not observed, the only remaining solution is solution d). This shall be considered in particular in cases where a junction is subsequently added to a road already in operation.

Exceptions to the *Verkettungsverbot* are permissible on EKA 3 motorways as long as the overall clarity of the directional signing is guaranteed.

If the actual junction spacing also falls below the minimum weaving length in accordance with Section 6.4.5, the only solution that can be considered is the one involving ‘crossover’ slip roads, which result in the shortest possible junction spacing of all (solution e) in Fig. 28. According to this solution, the weaving traffic flows cross each other using a grade-separated flyover. With this solution, as is the case with solution b), it is assumed that the traffic between the two junctions is absorbed by the subsidiary network. If not, a direct link (optional slip road in Fig. 28) should be constructed between the two ‘crossover’ slip roads to accommodate the excluded movements (outer non-weaving flow).

Even in those cases where junctions are not closely spaced, the solution involving ‘crossover’ slip roads is also used to improve the flow of traffic over longer weaving sections between two junctions. This way, weaving areas on both mainline carriageways and link roads can be replaced by the ‘crossover’ slip roads. If the motorway junction in question is a four-way or three-way interchange, the optional slip road for the outer non-weaving flow shall be laid out in accordance with Fig. 28.

If, in exceptional cases, the *Verkettungsverbot* on EKA 3 motorways is not observed, the dense succession of uncontrolled entries and exists can significantly hamper the traffic flow. If a close succession of junctions is necessary as a result of the network structure or the presence of constraints, operational measures



a) Use of the outer quadrants (optimized slip road layout)

b) Partial junctions (example shown here: half-diamond interchange)

c) Weaving lanes on the through carriageway (example shown here: two junctions)

d) Long link road (example shown here: two junctions)

e) 'Crossover' slip roads (example shown here: two junctions)

Legend: ○ at-grade partial junction
– – – optional slip road

Fig. 28: Possible solutions to situations where junctions are closely spaced (schematic, only one carriageway is shown)

in accordance with Section 7.10 (e.g. ramp metering) should be examined in addition to engineering solutions in accordance with Fig. 28.

Moreover, in the case of a close succession of junctions with intervals that are shorter than the minimum values given in Table 20, an analysis of the traffic flow over the entire junction sequence and all weaving sections must be provided in addition to evidence of the quality of the traffic flow in accordance with the HBS. It is recommended that the traffic flow be simulated using suitable computer software.

6.2.3 Alignment of the mainline carriageways

At EKA 1 A four-way interchanges, mainline carriageways should not turn but essentially continue through the interchange; at three-way interchanges, mainline carriageways should follow the dominant turning movement on the network.

On EKA 1 B and EKA 2 motorways, the mainline carriageway at four-way interchanges can only follow a dominant turning stream if its traffic volume justifies this solution, the long-term traffic forecast is reliable, and only minor shifts in traffic movement are to be expected in the event of the development of the network.

At four-way and three-way interchanges that link EKA 3 motorways only, the position of the mainline carriageway primarily depends on the conditions that control traffic flows and the required capacities. For this reason, the general rule is that the mainline carriageway should be specified on the basis of traffic load.

In principle, the **cross-sections** of the mainline carriageways around junctions are the standard cross-sections for motorways (Section 4). In well-founded exceptional cases, the hard shoulder near the junction can be dispensed with over a short distance on EKA 2 and EKA 3 motorways and when reconstructing and improving EKA 1 motorways.

The **geometry** of the mainline carriageway is based on Section 5. Moreover, the following instructions regarding the alignment of the mainline carriageway around junctions must be observed:

– The route parameters of the mainline carriageway should be much higher than the limiting values in the area around the junction. Entries and exits should be positioned on straights and not in curves.
– Because of poor visibility in the rear-view mirror, **entries** should not be laid out in tight right-hand curves. For reasons of visibility when merging, a minimum radius, R, of 800 m on EKA 2 motorways and R equal to 400 m on EKA 3 motorways should be used on entries on right-hand curves. Otherwise, a change of the junction system should first be considered and then a change of the entry geometry, which would ensure the parallel movement of vehicles entering the motorway at an early stage.
– Around **exits**, the horizontal radius, R, should not fall below 800 m on EKA 2 motorways and 400 m on EKA 3 motorways to ensure a safety reserve should it become necessary to apply the brakes in a curve and to ensure that the nose of the island is visible in the angular field of 15 gon (13.5°). In the case of an exit on a left-hand curve, designers shall ensure that the alignment of the mainline carriageway is clearly identifiable: the exit slip road should, therefore, begin with a clear right-hand curve and then a left-hand curve and should not lead straight off the mainline carriageway.
– The longitudinal gradient of the mainline carriageway should not exceed 3 % at the junction so that the slip road has acceptable geometry; avoid excessively long slip roads as a result of an ‘extended’ section with an acceptable longitudinal gradient).

At junctions, the crest diameters of the subsidiary road that has to be planned in accordance with RAL or RASt should be dimensioned around the slip road connections in such a way as to ensure adequate visibility.

Junctions near major valley crossings (EKA 1) can lead to extended junctions with long slip roads or special local distributor roads (indirect access). In these cases, for cost reasons, designers should consider whether it would not be better to move the junction to a more suitable location or whether the vertical alignment of the motorway could be changed.

6.3 Junction systems

6.3.1 General remarks

A number of standard systems are available for frequently used grade-separated and partially grade-separated junction designs (Sections 6.3.2 and 6.3.3). Designers should not deviate from these standard systems without good reason. These systems can be broken down into three-leg and four-leg systems. Situations in which more than four legs occur, i.e. where there is a combination of four-way interchanges/three-way interchanges and junctions, should, where possible, be divided up into three- and four-leg junctions. If this is not possible because of the network configuration or spatial constraints, the four-way interchange design should be modified in order to come up with special solutions. As a rule, this leads to a disproportionally high increase in the number of structures (bridges and the like) and land acquisition requirements.

Detailed recommendations regarding suitable systems and the advantages and disadvantages of all systems are listed for each individual design class. When selecting the most suitable junction system, it is important to weigh up the following considerations carefully:

– capacity (e.g. avoidance of weaving sections within the junction itself),
– the number of structures,
– land acquisition requirements, and
– total structure height (number of levels).

Depending on the circumstances, more closely spaced consecutive junctions may influence the choice of system (Section 6.2.2).

When it comes to four-way interchanges within built-up areas, unfavourable topography and a lack of available land in particular can make it necessary to come up with special solutions. Changes to the standard systems affect either the alignment of the slip road (distortion, shift to a different quadrant) or the dispensing with entire slip roads. Dispensing with slip roads, especially in junctions with more than four legs, should only be considered for low turning streams or in cases where the excluded movements are absorbed by a connected network link. In this case, it is preferable that both slip roads in both directions should be dispensed with because asymmetrical solutions are not easily understood by drivers who are not familiar with the area and it is not always possible to explain them clearly on road maps.

Moreover, assessments should be carried out to determine whether the use of operational measures (such as ramp metering, lane signalling, or variable allocation of directions to lanes in the sorting area) would reduce the number of structures while maintaining junction capacity (Section 7.10).

The grade separation structures in the sketches of the different systems are portrayed as either overpasses or underpasses. In terms of

- level of service (dynamics of vehicle movement, capacity),
- road safety (visibility), and
- structural content,

these structures constitute the best solution in each case. For this reason, overpasses and underpasses should not be switched without compelling reasons (e.g. topography).

Changes to the standard systems or other combinations of sections of systems are acceptable as long as their layout is clear and signing is easily understandable, thereby ensuring smooth traffic guidance and good orientation.

The uniform design of the sections of the system is more important than the application of uniform junction systems.

Exits should always be located upstream of entries on the mainline carriageway. Otherwise, a link road should be included in order to keep weaving manoeuvres away from the mainline carriageway.

6.3.2 Grade-separated junction systems

6.3.2.1 Four-way interchanges

For four-way interchanges and four-leg junctions that connect motorways and EKL 1 rural roads in accordance with the RAL, the position of heavy turning streams is important when it comes to the choice of junction system (Fig. 29). The individual systems can be subdivided into three groups according to their turning stream capacity, which is largely determined by the weaving areas and their capacity:

a) systems with four weaving areas (basic cloverleaf interchange layout and all its variants: Fig. 30 and Fig. 31),

b) systems with one or two weaving areas (modified cloverleaf interchange with a semi-direct slip road: Fig. 32 and Fig. 33 – left-hand system; modified windmill interchange with two loops in symmetrical quadrants or with three loops),

c) systems without weaving areas (modified cloverleaf interchanges with two semi-direct slip roads positioned in diagonal quadrants: Fig. 33 – right-hand system; modified cloverleaf interchange with grade-separated crossover weaving flows: Fig. 34; windmill interchange with modifications: Fig. 35; stack interchange: Fig. 36).

In terms of subsequent increases in traffic load, it should be noted that the systems belonging to group a) can only be extended at great expense and with great difficulty once the weaving areas have reached their capacity, and that there are limits to the extension possibilities for group b). For systems belonging to group c), the turning stream capacity is determined by the capacity of the respective entry types at the end of the slip road.

The choice of a suitable junction system can be made on the basis of the position and size of the turning streams in accordance with Fig. 29. Depending on the intensity of the other turning streams, which may have to be crossed in a weaving section, traffic volumes of between 1,200 and 1,400 vehicles per hour are considered heavy turning streams. The capacity calculated in accordance with the HBS is used in this evaluation. In those cases where several systems are indicated on a single line in Fig. 29 and all conditions are otherwise the same, the right-hand system produces higher-quality traffic flows. However, these systems are also more complex in terms of land acquisition and more costly in terms of construction, operation, and maintenance.

In a scheme characterized by three heavy turning streams, a solution for four heavy turning streams should be considered in accordance with Fig. 29 because the additional work and expense is comparatively low.

In general, the following applies:

- a cloverleaf interchange should always be used in those cases where the traffic load allows for such a solution while at the same time ensuring adequate traffic flow quality;
- a stack interchange should only be used in cases where a very high junction load necessitates such a design.

In principle, both systems can be used in all combinations of design classes where motorways intersect.

In a cloverleaf interchange, it is only permissible to replace the link road with a weaving lane on the mainline carriageway for the following design classes: EKA 1 B, EKA 2, and EKA 3. In individual cases, the weaving area

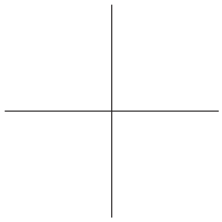
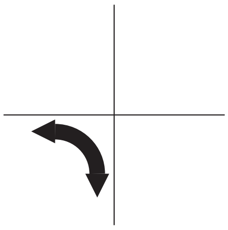
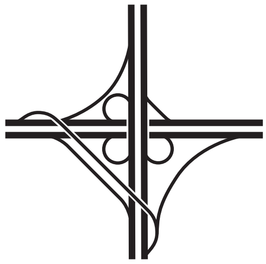
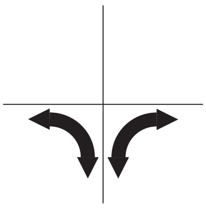
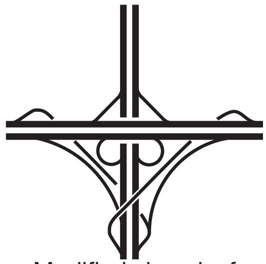
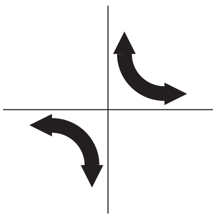
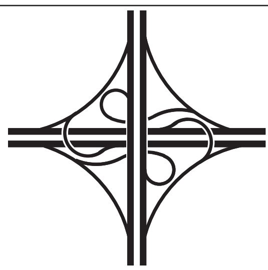
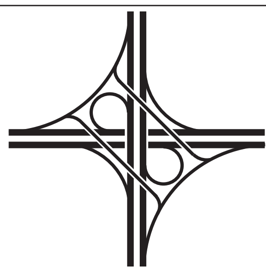
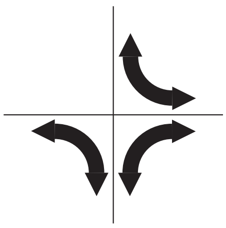
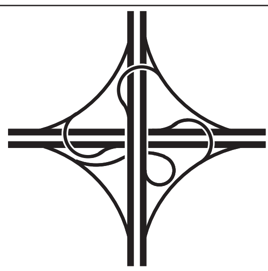
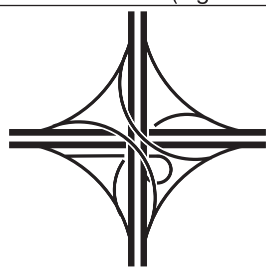
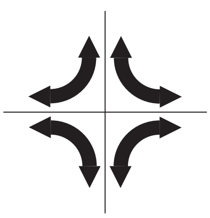
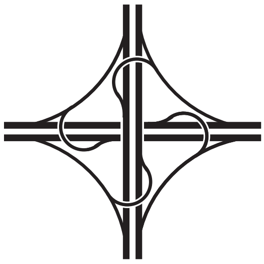
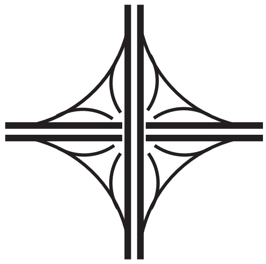
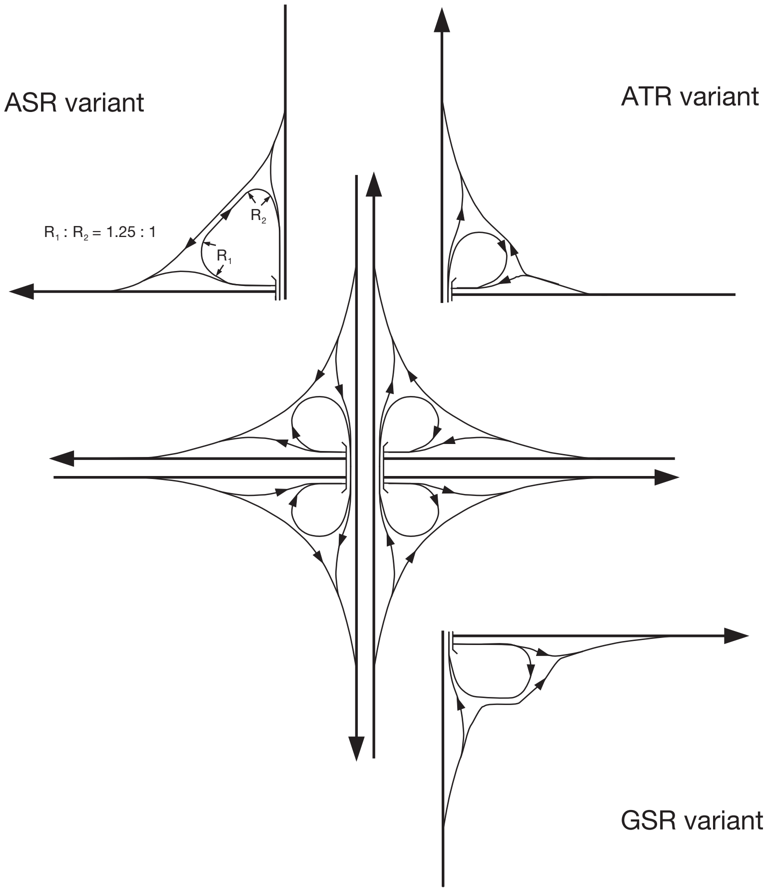
Position of the heavy turning streams	Suitable systems	
	 Basic cloverleaf layout (EKA 1: Fig. 30, EKA 2 and 3: Fig. 30 and 31)	
	 Modified cloverleaf (Fig. 32)	 Modified cloverleaf (Fig. 33 left)
	 Modified windmill	 Modified cloverleaf
	 Modified windmill	 Modified cloverleaf (Fig. 33 right)
	 Modified windmill (Fig. 35 right)	 Modified stack
	 Windmill (Fig. 35 left)	 Stack (Fig. 36)

Fig. 29: Recommendations for the application of four-way interchange systems



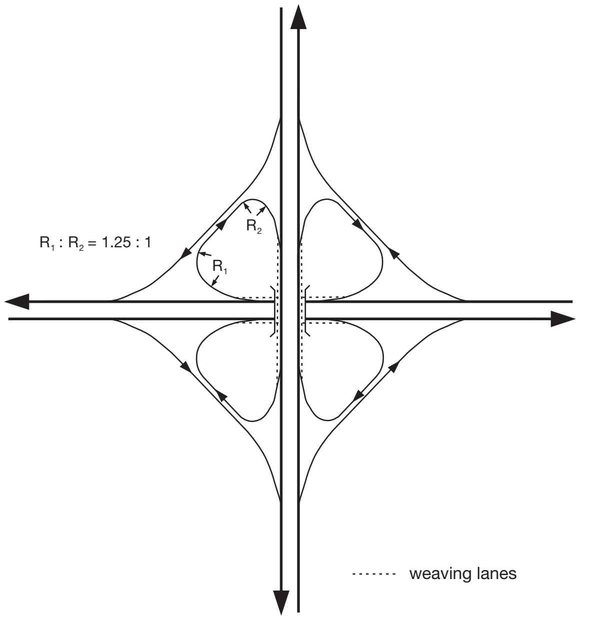
Advantages:	– Only one structure – Loops with relatively large radii – Relatively even traffic movement paths – Offers the ability to turn around (U-turn), favourable for operation and winter maintenance services
Disadvantages:	– Four weaving sections – Capacity limitation for traffic turning from one motorway to another – High land acquisition requirements (if the weaving sections are sufficiently long) or – Relatively short weaving sections (if land is at a premium) – Extensive structure
GSR variant: Objectives:	Elongated loop (EKA 1) – To achieve longer weaving sections (along the same axis) – To achieve longer slip road development lengths, which are necessary for extended longitudinal gradients
ASR variant: Objectives:	Adapted (‘compressed’) loop (EKA 2 and 3) – To achieve longer weaving sections (in conjunction with smaller loop radii) – To achieve shorter junction areas
ATR variant: Objectives:	Adapted tangential slip road – To reduce land acquisition – To achieve shorter junction areas

Fig. 30: Cloverleaf (basic layout) with slip road design variants

is assessed in accordance with Section 6.4.5. Evidence of the quality of the traffic flow in the weaving area shall be provided in accordance with the HBS or a suitable simulation programme.

The least expensive solution for a four-way interchange is the basic **cloverleaf system** and its variants.

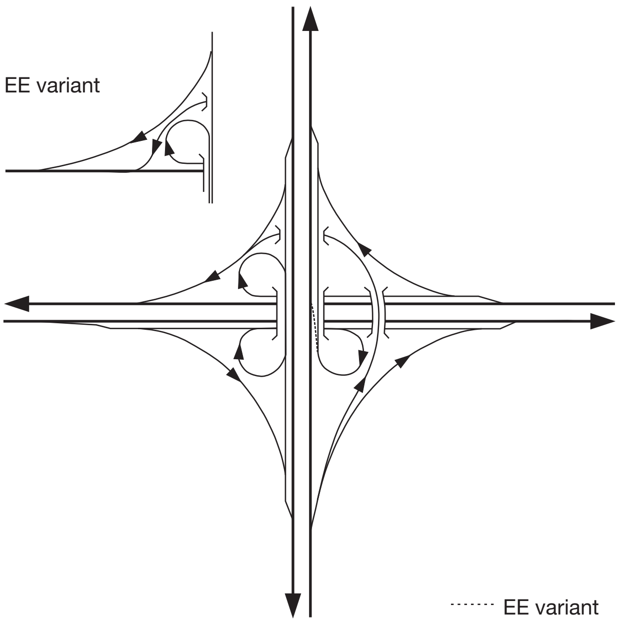
Cloverleaf (**basic layout**, Fig. 30): the cloverleaf interchange in its basic form requires only one structure with two levels. However, due to its loops, it also takes up a lot of space. The level of service is determined by the four weaving sections, which restrict the capacity of the entire system in cases characterized by heavy turning streams. Another effect of traffic guidance on the cloverleaf interchange is that the high-capacity, fast tangential slip roads are available for right-turning traffic streams and that only the lower-capacity, speed-reducing loops are available for left-turning traffic streams. On the other hand, loops and weaving sections are the prerequisite for turning movements in a cloverleaf interchange (e.g. there is potential for concern for operations and winter maintenance services).



Advantages: – Small grade separation structure
– Less land required

Disadvantages: – Limited weaving section capacity because of weaving on the mainline carriageway
– A speed limit is necessary on the mainline carriageway

Fig. 31: Cloverleaf interchange variant without link roads



Advantages: – No weaving sections
– Faster slip roads than is the case in the basic cloverleaf layout
– Improved level of service in the semi-direct slip roads

Disadvantages: – Three structures
– Greater land acquisition requirements than is the case with the basic cloverleaf layout
– Vehicles are unable to turn around from all approaches

EE variants: EE-type entry

Objective: – To improve traffic flow when the traffic load on the slip roads is high

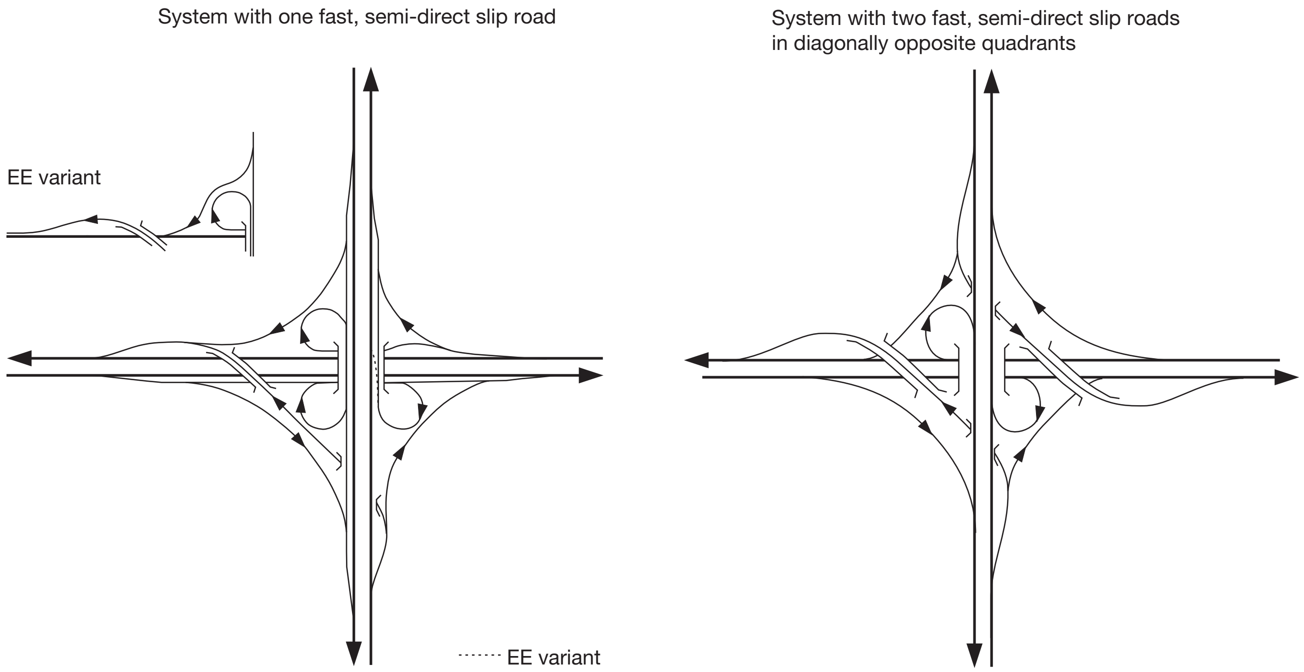
Fig. 32: Modified cloverleaf interchange with semi-direct left-turning traffic streams

In its basic form, the cloverleaf interchange has both link roads and circular loops. Where possible, pivoted link roads must be used because they make the exit areas leading to the tangential ramps more clearly visible, increase the distance between T-junctions on entry slip roads, and, therefore, facilitate the design of merging lanes within the link road. The weaving section between the loops can be extended by making sure that the pivoted sections on both sides are extended into the weaving section and the link road only runs parallel to the mainline carriageway around the actual grade separation structure. As long as they have correspondingly large radii, the loops allow for similar traffic movement paths.

Cloverleaf with elongated loops (Fig. 30 – GSR variant, EKA 1): elongated loops are used when long weaving sections need to be created along an axis, when large development lengths are needed for the slip roads because of the steep (extended) longitudinal gradient of the motorways being connected, or when local conditions (development, protection of adjacent land) necessitate such a layout.

Cloverleaf with adapted (compressed) loops and/or adapted tangential slip roads (Fig. 30 – ASR and ATR variants, EKA 2 and 3): the adjustment of the slip roads results in longer weaving sections on the link roads, generally involves lower land acquisition requirements, and results in a shortening of the junction areas. In the area of entry, it will be necessary to make do with a small radius if the land acquisition requirements are not to increase due to the circular loops. In the interest of even traffic progression in the loop, the ratio of radius R1 : R2 should be 1.25 : 1 at the most. If reverse curves are used in the adapted tangential ramps, drainage problems may occur as a result of the necessary change in crossfall. Moreover, the edges of the carriageway may appear to ‘flutter’ from the driver’s perspective.

The **cloverleaf without link roads** (Fig. 31, EKA 2 and 3) should only be used in exceptional cases with low traffic volumes. For this variant of the basic layout, individual link roads or all link roads are replaced by weaving lanes on the mainline carriageway. This solution requires adapted loops; otherwise the necessary weaving distance cannot be provided. This variant reduces both the construction costs for the central grade separation structure and the land acquisition requirements. It can be used when the capacity of the weaving section is sufficient and the entry radius of the loop is at least 40 m. Imposing a speed limit of 100 km/h or less on the mainline carriageway is necessary to ensure safe vehicle weaving and must, therefore, be agreed with the responsible traffic authority. The cloverleaf without link road layout breaks the ‘exit before entry’ rule on the main carriageway and consequently makes greater demands on directional signing.



Advantages:	– Dispenses with two weaving sections (with all weaving sections in the system on the right)
	– Faster ramps than is the case with a semi-direct left-turning traffic stream
	– Better level of service on the semi-direct slip road(s)
Disadvantages:	– Three structures (five in the system on the right), some of which have very acute-angled intersection angles
	– Higher land acquisition requirements than is the case with semi-direct slip roads for a left-turning traffic stream (much higher land acquisition requirements in the system on the right)
	– Limited opportunities for drivers to turn around
EE variants:	EE-type entry
Objective:	– To improve traffic flow on slip roads characterized by high traffic loads

Fig. 33: Modified cloverleaf layouts with fast, semi-direct left-turning traffic streams

In addition to the basic layout, there are a variety of **modified cloverleaf systems with semi-direct slip roads for left-turning traffic streams** (Fig. 32 and Fig. 33). These are used when the capacity of one or more weaving sections in a basic cloverleaf layout is no longer sufficient, when the intention is to improve the quality of the traffic flow in turning movements using faster slip roads, or when topographical constraints do not allow for a conventional cloverleaf layout.

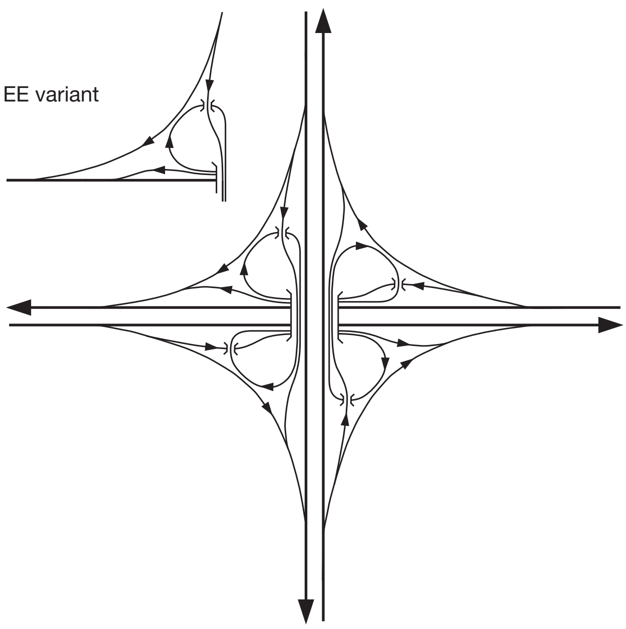
In Fig. 32 and Fig. 33 (left-hand system), each of the illustrated solutions is shown with a semi-direct slip road, whereby two weaving sections are dispensed with. If two diagonally opposite loops in a cloverleaf interchange are replaced by semi-direct slip roads, all weaving sections are dispensed with, a move that significantly increases capacity and significantly improves the level of service for turning movements (Fig. 33, right-hand system).

If the link roads in the illustrated junction systems continue straight into loops, further measures may be necessary (for instance carriageway markings, directional signs, speed limits, upstream reverse curves).

Because of the higher construction costs and the high land acquisition requirements of modified cloverleaf interchanges, before choosing such a layout designers should investigate the extent to which less expensive operational measures (such as ramp metering or lane signalling at entries and exits) could be used to improve the quality of the traffic flow (Section 7.10).

Modified cloverleaf with grade-separated crossover of the turning streams: once the capacity of the weaving sections in an existing basic cloverleaf layout has been exceeded, the junction can be upgraded to allow for the grade-separated crossover of the weaving flows in accordance with Fig. 34. The prerequisite for this solution – which is not a standard system for a new-build scheme – is, however, either that the existing cloverleaf already has a very high land acquisition requirements or the corresponding land required for the extension is available. Otherwise there will not be enough space for the development lengths of the flyover link roads and the loops. The disadvantage of this solution is the limited quality of the traffic flow in the flyover area of the slip roads with their low geometry standards (small crown radii, small crest diameters).

The **windmill** junction system and modified windmill systems with individual loops (Fig. 35) are used in cases where there are land restrictions for the semi-direct slip roads of a modified cloverleaf layout and small geometry elements consequently would have to be used.



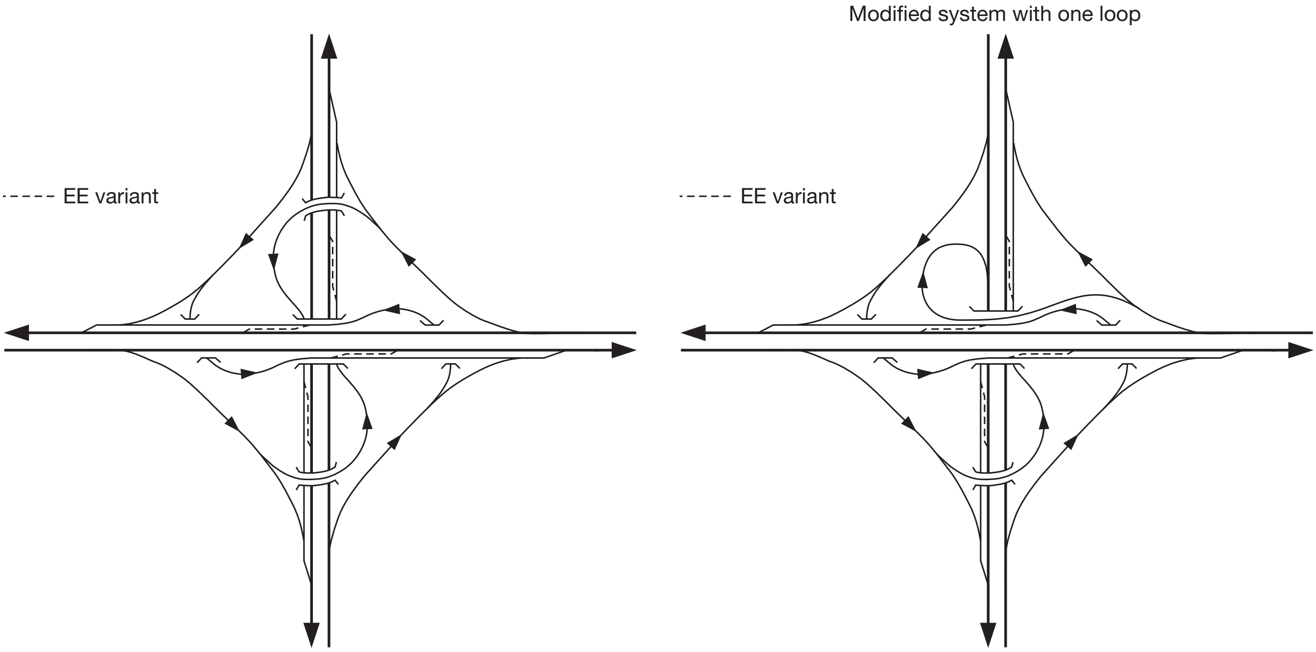
Advantages:	– Dispenses with all weaving sections – Traffic flow is not interrupted by improvement works
Disadvantages:	– Unfavourable loop arrangement (lower visibility, lost ascending gradients, additional carriageway length) – Four additional structures – High land acquisition requirements – A large area of the central grade separation structure has to be built over
EE variant:	EE-type entry
Objective:	– To improve traffic flow when the traffic load on the slip roads is high

Fig. 34: Modified cloverleaf with grade-separated crossover of the turning streams (for improvement and extension schemes only)

When determining the geometry of the slip roads, designers shall pay particular attention to observing the maximum longitudinal gradient and the necessary stopping sight distance in the crest areas.

In the case of modified windmill systems, the exit leading to the loop should be positioned upstream of the introduction of the semi-direct slip road; otherwise a speed-reducing weaving area in the junction will be created (Fig. 35: modified system with a loop).

In the case of the systems outlined above, if the traffic load on the slip roads is heavy, it may be conducive to connect the tangential ramps to the mainline carriageway independently of the link roads or the semi-direct slip roads (Fig. 32 to Fig. 35, EE variant in each case).



Advantages:
- No weaving sections
- Relatively low land acquisition requirements

Disadvantages:
- Five structures
- Relatively steep longitudinal gradients and unfavourable visibility on the crests as a result of the small geometry elements on the semi-direct slip roads
- No opportunities for vehicles to turn around; unfavourable for operation and winter maintenance services

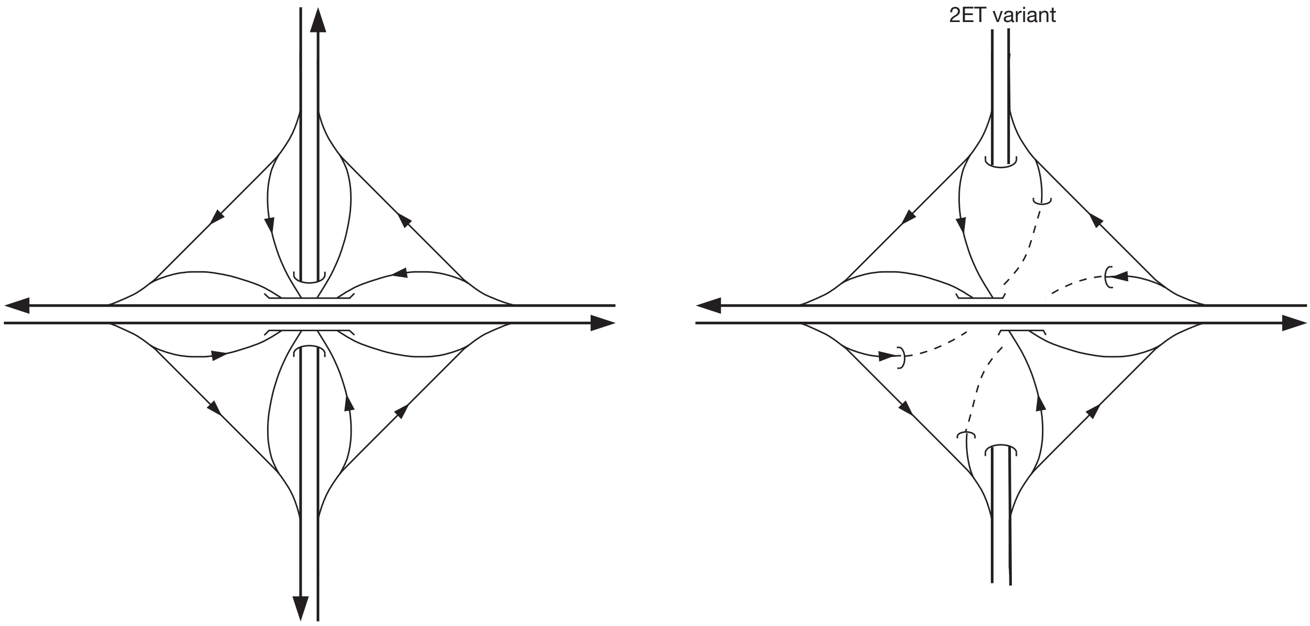
Objective: – To save on one structure

EE variant: EE-type entry

Objective: – To improve traffic flow when the traffic load on the slip roads is high

Fig. 35: Windmill and modified system

The **stack** junction system (Fig. 36) is the most generously proportioned four-way interchange solution. It has a smaller number of structures than the windmill interchange. However, depending on circumstances, it can have higher land acquisition requirements. The grade separation structure with four levels can be visually intrusive on the landscape or the urban environment. One variant of the stack interchange, which features two levels running underground (Fig. 36, 2ET variant) helps keep down the overall height of the central grade separation structure, thereby reducing its negative impact in terms of town planning. According to this layout, the mainline carriageways on a through motorway and the semi-direct slip roads of two opposite turning movements largely pass through tunnels. For reasons of expedience, the crossing points of the central structure are spaced out, which consequently increases the land acquisition requirements of the junction. In view of the generous geometry elements of the stack interchange, the underground alignment does not impair road safety in any way.



Advantages:
- Fast traffic flows in all directions
- Large turning stream capacities

Disadvantages:
- Central grade separation structure with four levels
- Long junction areas
- No opportunities for vehicles to turn around, unfavourable for operation and winter services

2ET variant: 2 levels underground (tunnel)

Objectives:
- To reduce overall height
- More suitable for urban locations

Disadvantages:
- Higher construction and operation costs
- Somewhat higher land acquisition requirements

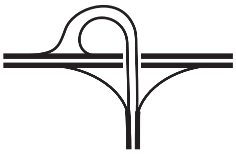
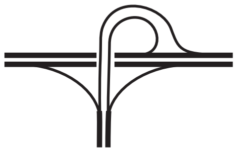
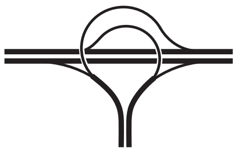
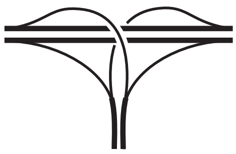
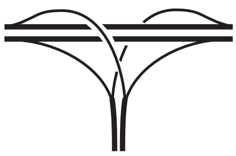
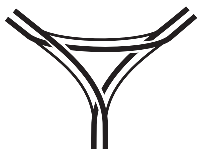
Fig. 36: Stack interchange

6.3.2.2 Three-way interchanges

Three-leg junction systems have one fundamental disadvantage, namely the fact that one mainline carriageway passes directly into an entry. Three-way interchanges have no weaving sections, which means that there is no opportunity for drivers to turn around.

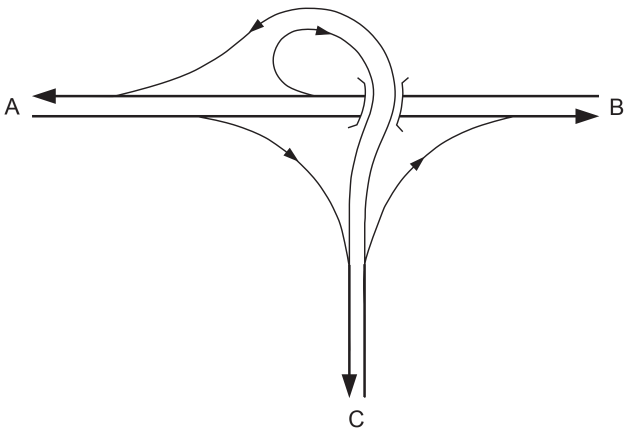
Fig. 37 lists the suitable junction systems for three-way interchanges and for three-leg junctions that connect motorways and EKL 1 rural roads in accordance with the RAL. Suitability is determined on the basis of the design classes of the through carriageway and the connected road. For reasons of network hierarchy, the connected road should belong to the same design class as the through carriageway.

The least expensive three-way interchange solution is the **trumpet interchange**. It should only be utilized for junctions where deceleration to low speeds – also on the mainline carriageway – is justifiable. In order to ensure that drivers recognize the small radius at the end of the mainline carriageway in good time, the slip road main curve should begin before the grade-separation structure. An upstream reverse curve can make it easier to recognize the course the road takes and help to reduce speed.

Design class of the through motorway		**EKA 1**	**EKA 1**	**EKA 1**	**EKA 2**	**EKA 2**	**EKA 3**
Design class of the connected motorway ('third arm')		**EKA 1**	**EKA 2**	**EKA 3**	**EKA 2**	**EKA 3**	**EKA 3**
'Left-facing' trumpet (Fig. 38)		+	+	+	+	+	+
'Right-facing' trumpet (mirror image of Fig. 38)		–	–	•	•	•	•
'Pear' (Fig. 39)		•	•	•	•	+	+
T-interchange with one structure (Fig. 40)		+	+	+	+	+	+
T-interchange with three structures (Fig. 41)		+	+	+	+	+	+
Y-interchange, without uniform definition of mainline carriageways (Fig. 42)		–	–	–	–	–	+

Legend: + suitable • of limited suitability – unsuitable

Fig. 37: Recommendations for the application of systems for three-way interchanges

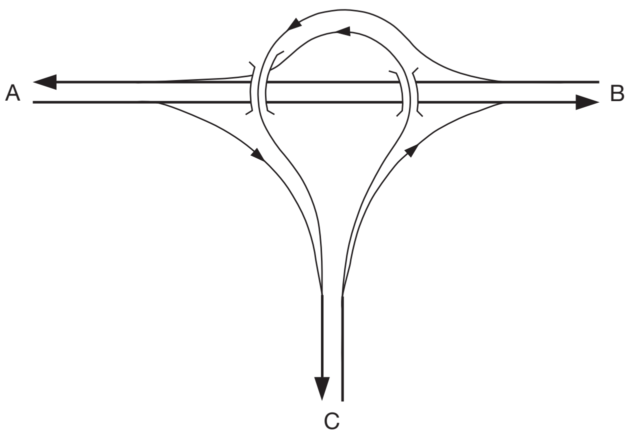


Advantages:	– Only one structure – Low land acquisition requirements – Expedient for low turning movement B–C and high turning movement C–A
Disadvantage:	– Carriageway terminates at an entry
Mirror-image variant:	'Right-facing' trumpet (not shown)
Objective:	– To adapt the junction to topography, land availability – To adapt to low turning movement C–A and high turning movement B–C
Disadvantage:	– Carriageway terminates in a loop

Fig. 38: 'Left-facing' trumpet

For reasons of road safety, the **'left-facing' trumpet** (Fig. 38) is the standard solution. Here, traffic movements C–A are directed quickly from the directly connected motorway into a left-hand curve of constant curvature. If the movement A–C is a heavily dominant turning stream, a special solution featuring a flyover slip road B–C or the marking of a slip road B–C with subsequent addition of the turning movement A–C can be expedient.

'Right-facing' trumpets (mirror-image variant of Fig. 38) must be avoided. The disadvantage of this layout is that the traffic on the connected motorway has to drive on a curve of decreasing radius (right down to the loop radius) without an upstream exit. If there is no other option, additional measures (directional signs, speed limits etc.) should be used to counteract this disadvantage.

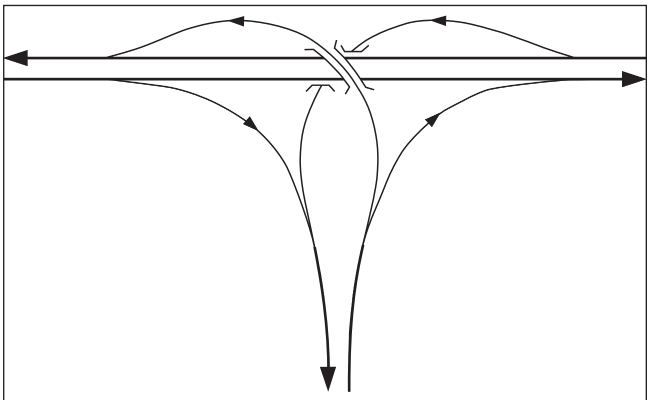


Advantages:	– Relatively low land acquisition requirements – Two structures – Expedient for high turning movement B–C and low turning movement A–C
Disadvantages:	– Parallel alignment of an ascending and a descending slip road – Carriageway terminates at an entry
Mirror-image variant:	'pear' with preference given to the turning movement A–C (not shown)
Objective:	– To adapt to turning stream load patterns

Fig. 39: 'Pear'

The **'pear'** system (Fig. 39) avoids the shortcoming of the trumpet interchange; it does not have a loop. Fig. 39 shows a 'pear' interchange with preference given to the movement B–C. A mirror-image solution would result in a 'pear' with preference given to the movement A–C.

In the **three-level T-interchange with one grade-separation structure** (Fig. 40), all left-turning diagonal traffic streams are semi-direct. The structural content and land acquisition requirements are both higher than is the case with the trumpet. It is used in cases where the turning streams are high.

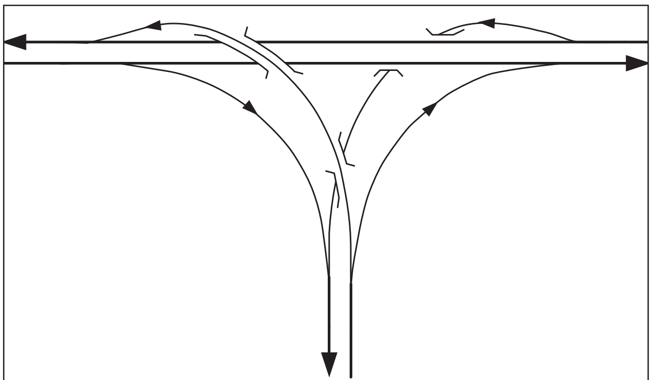


Advantages:
- Expedient in cases where the turning streams have relatively similar volume
- Lower land acquisition requirements than the T-interchange with three grade-separation structures

Disadvantages:
- Grade-separation structure with three levels
- Total structure height
- Higher land acquisition requirements than the 'pear'
- Carriageway terminates at an entry

Fig. 40: Three-level T-interchange with one grade-separation structure

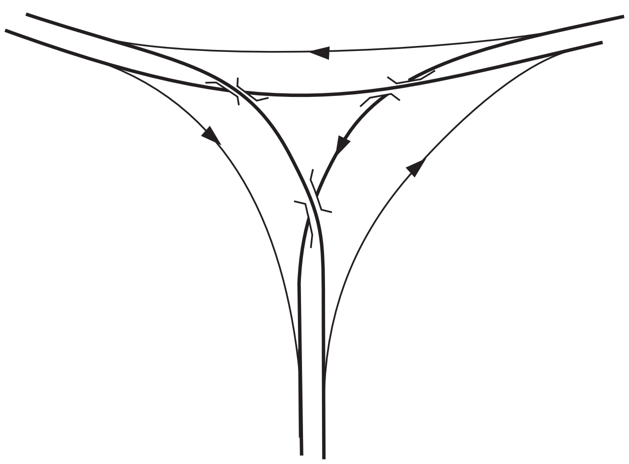
The **T-interchange with three grade-separation structures** (Fig. 41) is the most generously proportioned three-way interchange system. All turning streams are either direct or fast, semi-direct. The system is based on the solution in Fig. 40, whereby the loops are separated spatially and the single three-level grade-separation structure is broken down into three separate structures. As a result, this solution has relatively high land acquisition requirements.



Advantages:
- Expedient in cases where the turning streams have relatively similar volumes
- Fast, direct traffic routing
- High capacity

Disadvantages:
- Three structures with acute intersection angles
- High land acquisition requirements
- Carriageway terminates in an entry

Fig. 41: T-interchange with three grade-separation structures

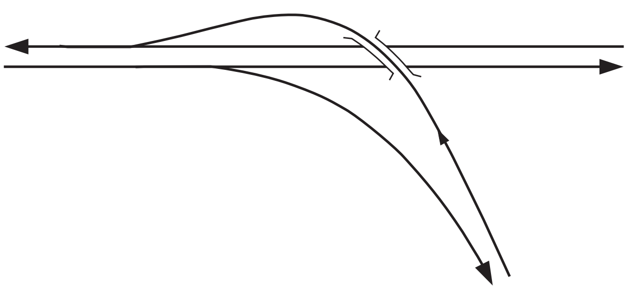


Advantages: – Avoidance of flyovers over the through carriageway, which results in smaller structures
– No reverse curves in the horizontal alignment ('direct slip roads' for left-turning diagonal traffic streams)
– Slightly lower land acquisition requirements than for the system in Fig. 37

Disadvantage: – No clearly defined through motorway

Fig.42: Y-interchange without uniform definition of mainline carriageways

The **Y-interchange without uniform definition of mainline carriageways** (Fig. 42) is a modified variant of the T-interchange with three grade-separation structures. This is the only system in which mainline carriageways do not terminate at entries. However, when choosing this solution, designers must accept that the specification of the mainline carriageways in terms of the forward and opposite direction is no longer symmetrical. The solution is expedient in cases where turning streams have almost the same volume. In view of the fact that this layout features single-carriageway grade-separation structures only, the structural content is lower than for the system in Fig. 41. Exits and entries must be designed as lane drops and lane gains. Here too, operational measures can be introduced to improve the traffic flow.



Advantages: – Fast routing of traffic in all directions
– Low land acquisition requirements
– Only one single-carriageway structure

Disadvantage: – Some turning movements excluded

Fig. 43: Grade-separated fork junction (motorway turnoff)

The **grade-separated fork junction** (Fig. 43) is a special form of three-way interchange that provides no carriageways for two low turning streams. The excluded traffic movements should be catered for at a different point on a connected link. Alternatively, the land required for a subsequent construction of the missing slip roads should be kept free and used in the intervening period as temporary access roads for road operation services.

6.3.3 Systems for partially grade-separated junctions (Anschlussstellen)

6.3.3.1 General remarks

Junctions consist of an exit and an entry for each carriageway, the corresponding slip roads, and a grade-separation structure. The exit and entry slip roads are connected to the subsidiary road by at-grade partial junctions. These are

- generally designed as a T-junction with or without traffic lights, or
- as a roundabout.

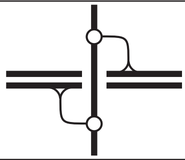
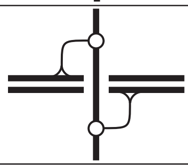
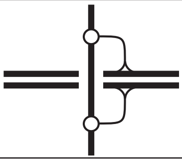
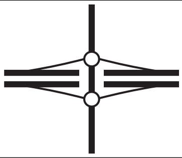
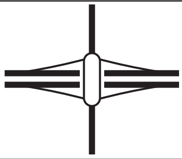
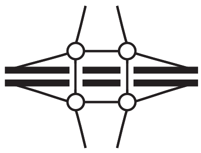
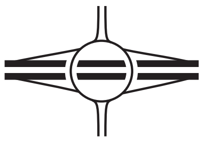
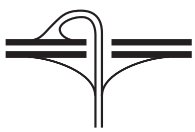
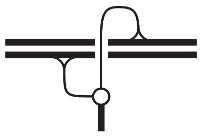
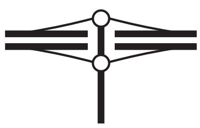
The choice and design of junction is based on either the RAL or the RASt. Evidence of the quality of the traffic flow is evaluated in accordance with the HBS.

Designers should make sure that no queues occur on the exit slip road right back to the motorway for the forecast traffic volume at an at-grade partial junction. For this reason, future extension possibilities for the selected system in the event of unexpected excess loads at the junction or the subsidiary road should be taken into consideration.

The design of at-grade partial junctions must be co-ordinated with the entire system of junctions/interchanges. When designing the queuing area of the at-grade partial junction, designers should consider the fact that while the left-turning lanes are more important at T-junctions without traffic lights, the area required for the necessary addition of turning lanes in the signal-controlled queuing area should be kept free in case traffic lights need to be added at a later date. Traffic lights or, in the case of low traffic load, a small roundabout are suitable solutions for subsequent connection of another road in the subsidiary network to the junction slip road in urban settings.

6.3.3.2 Four-leg junctions

Fig. 44 contains recommendations for the application of four-leg, partially grade-separated junction systems on the basis of the site of the junction. Systems are chosen on the basis of the regulations that apply to the subsidiary road (RAL, RASt). Evidence of capacity and the quality of traffic flow is evaluated in accordance with the HBS.

Junction system			EKA 1	EKA 2	EKA 3
Four-leg systems	Diagonal half-cloverleaf with exit upstream of the structure (Fig. 45)		+	+	•
	Diagonal half-cloverleaf with exit downstream of the structure (Fig. 46)		•	+	•
	Symmetrical half-cloverleaf (Fig. 47)		+	+	•
	Diamond with two intersections (Fig. 48)		–	•	+
	Diamond with one intersection (Fig. 49)		–	–	+
	Diamond with intersection that has been expanded in two axes (Fig. 50)		–	•	+
	Diamond with roundabout		–	•	+
	Special systems (mixed layout)		•	+	+
Three-leg systems	Junction with trumpet layout (Fig. 51)		•	+	+
	Half-cloverleaf (three-leg)		–	–	+ As an interim solution
	Diamond (three-leg)		–	–	+ As an interim solution

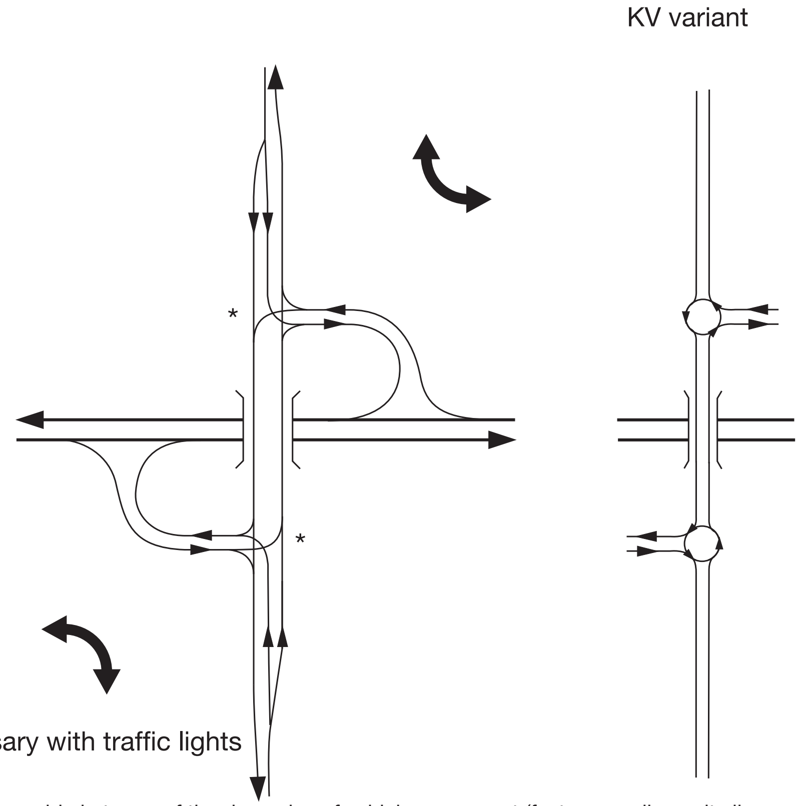
Legend: o at-grade partial junction + suitable • of limited suitability – not suitable

Fig. 44: Recommendations for the application of four-leg and three-leg partially grade-separated junction systems

The various standard systems as well as their respective advantages and disadvantages are described below.

There are three basic slip road arrangement possibilities for **half-cloverleaf** junction systems (Fig. 45 to Fig. 47). The advantages and disadvantages of each system are indicated in the respective figures. In the case of the half-cloverleaf layouts with slip roads in diagonally opposite quadrants (Fig. 45 and Fig. 46), turning movements can easily be channelled in both directions in the quadrants containing slip roads (double arrow in the diagrams) in the respective layout variants featuring T-junctions without traffic lights.

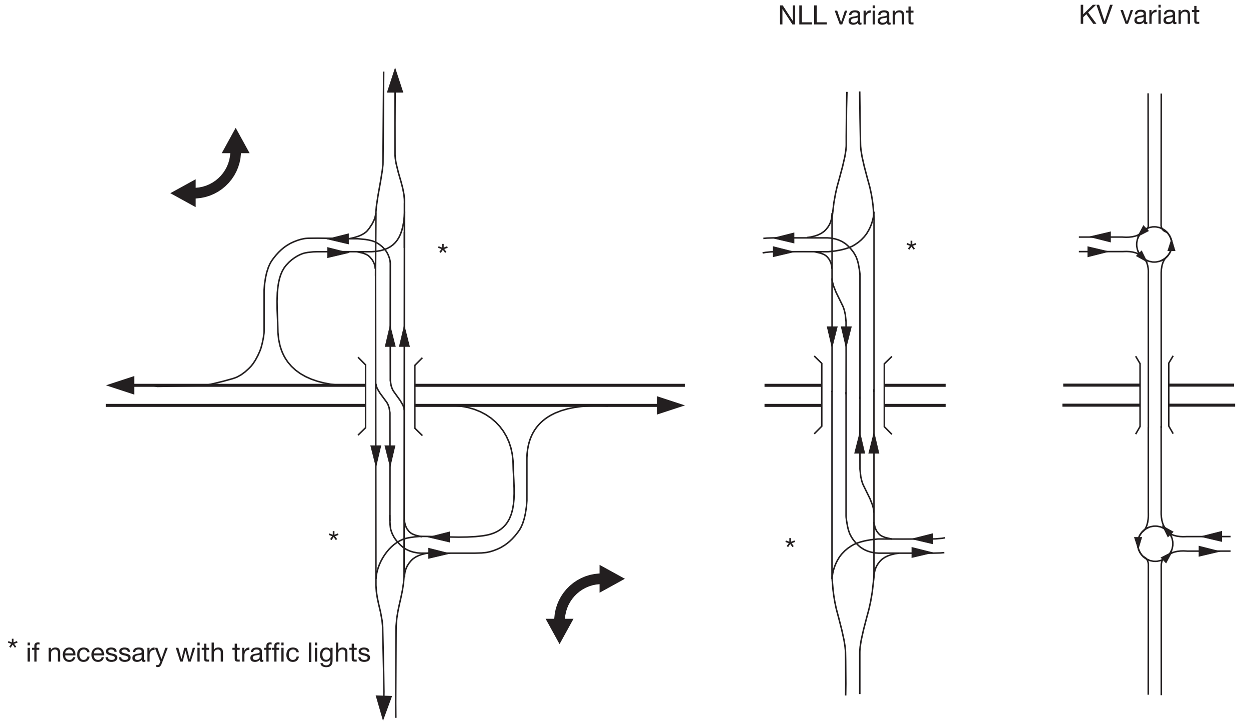
The **half-cloverleaf with slip roads in diagonally opposite quadrants and exits situated upstream of the grade-separation structure** (Fig. 45) is the most favourable system for junction traffic in terms of the dynamics of vehicle movement; it should be used whenever possible.



Advantages:	– Favourable in terms of the dynamics of vehicle movement (fast, ascending exit slip roads)
	– Unlimited possibility to extend the left-turning lane into the subsidiary road (not applicable in KV variant)
	– Expedient for heavy turning movement (shown by the double arrow)
	– Relatively narrow bridge required
	– Allows drivers to turn around, this is favourable for operation and winter maintenance services
Disadvantages:	– Major extension of the junction into the subsidiary road (this is not the case with the KV variant)
KV variant:	Small roundabouts
Objectives:	– To cover the capacity range between T-junctions without traffic lights and T-junctions with traffic lights
	– To avoid left-turning lanes
	– To minimize the spread of the junction into the subsidiary road
	– To minimize bridge width

Fig. 45: Diagonal half-cloverleaf with exit upstream of the grade-separation structure

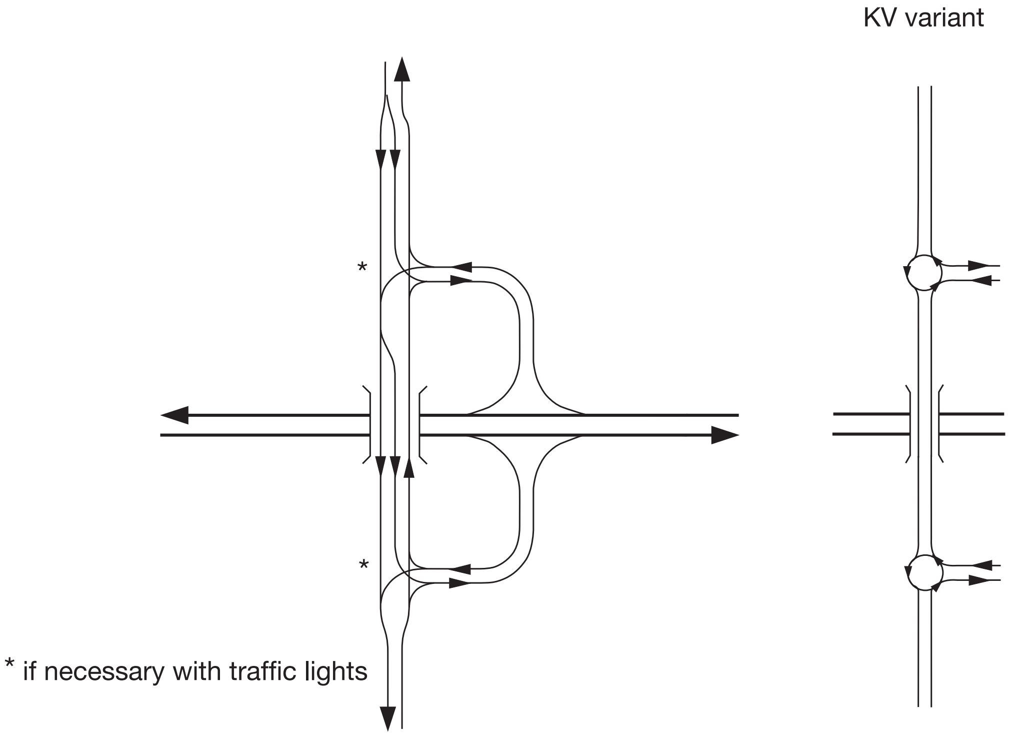
In the variants of the **half-cloverleaf with slip roads in diagonally opposite quadrants and exits situated downstream of the grade-separation structure** (Fig. 46) that feature T-junctions, the maximum length of the left-turning lane is restricted. The distance between the T-junctions must be based on the required length at the end of the construction phase. It is possible that the points at which the slip roads connect with the subsidiary road must be moved outwards.



Advantages:	– Low extension of the junction into the subsidiary road if the right-turning lane is dispensed with (this is not the case with the KV variant)
	– Expedient for heavy turning movements (shown by the double arrow) and/or land restrictions in the quadrants that are not utilized
	– Opportunity for drivers to turn around. Favourable for operation and winter maintenance services
Disadvantages:	– Unfavourable in terms of the dynamics of vehicle movement
	– No or only limited possibility to extend the left-turning lane into the subsidiary road (this is not the case with the KV variant)
	– Relatively wide bridge (this is not the case with the KV variant)
NLL variant:	Parallel left-turning lanes
Objectives:	– To increase capacity
	– To allow for closer spacing of slip road connection points
Disadvantage:	– Very wide bridge
KV variant:	Small roundabouts
Objectives:	– To cover the capacity range between T-junctions without traffic lights and T-junctions with traffic lights
	– To avoid left-turning lanes
	– To allow for closer spacing of slip road connection points
	– To minimize bridge width
Disadvantage:	– Queue on the exit slip road

Fig. 46: Diagonal half-cloverleaf with exit downstream of the grade-separation structure

In the **half-cloverleaf system with slip roads in symmetrically opposite quadrants** (Fig. 47), the close spacing of left-turning lanes on the subsidiary road necessitates careful directional signing (advance direction signs) in accordance with the RWBA and the RWB.

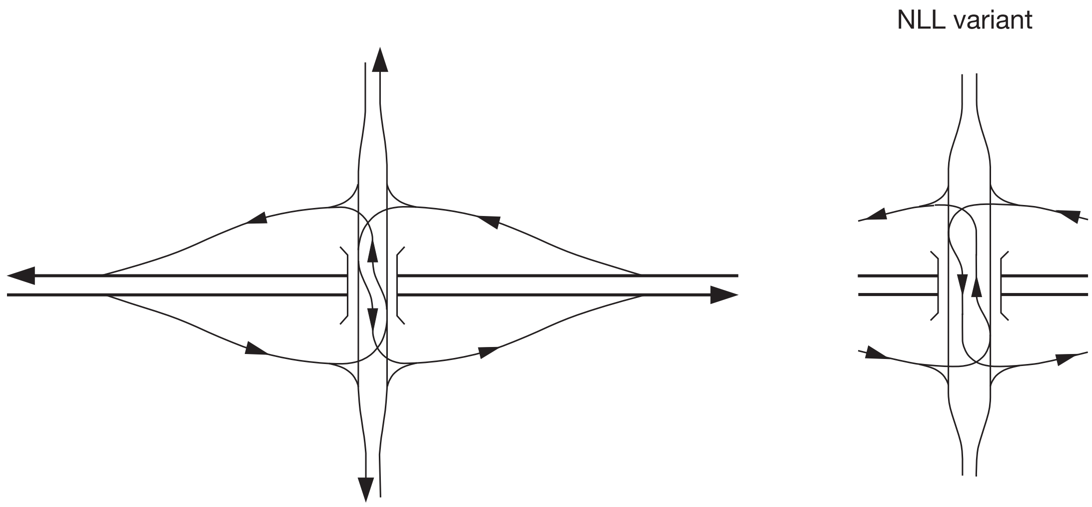


Advantages:	– Expedient in locations where land availability is restricted along one side of the subsidiary road
	– Turning opportunities, favourable for operation and winter maintenance services
Disadvantages:	– No one turning movement is given preference in both directions
	– Unsignalized T-junctions can only be used if the volumes of traffic turning left onto and off the motorway are low
	– One exit slip road is unfavourable in terms of the dynamics of vehicle movement
	– Relatively wide bridge if the length of the second left-turning lane is not restricted
KV variant:	Small roundabouts
Objectives:	– To cover the capacity range between T-junctions without traffic lights and T-junctions with traffic lights
	– To avoid left-turning lanes
	– To minimize bridge width

Fig. 47: Symmetrical half-cloverleaf

There is a parallel ramp in every quadrant of the **diamond** (Fig. 48 to Fig. 50). Because of their low land acquisition requirements and the fact that the junction area does not extend far into the subsidiary road, diamonds are particularly suitable for junctions with high traffic loads in built-up areas. The diamond is, however, more prone to wrong-way driving than the half-cloverleaf.

The **diamond with two intersections** (Fig. 48) without traffic lights can only be used in cases where the volume of left-turning traffic is low. In order to separate the two intersections, the parallel slip roads must be clearly spread out. In its basic form, there are two ways of laying out the queuing area. The decision in favour of one layout depends on whether the left-turning lanes are behind one another or beside one another (NLL variant). If the slip road connection points are evenly spaced along the subsidiary road, the NLL variant offers greater capacity.



Advantages:
- Favourable for motorway traffic in terms of the dynamics of vehicle movement
- High capacity layout where traffic lights are used
- Lower land acquisition requirements than the half-cloverleaf layout
- Junction does not extend far into the subsidiary road
- Opportunities for vehicles to turn around, favourable for operation and winter maintenance services

Disadvantages:
- Because of the close spacing of the intersections, this junction must be signal-controlled
- Prone to wrong-way driving
- Slip roads in all four quadrants
- Relatively wide bridge

NLL variant: Left-turning lanes alongside one another

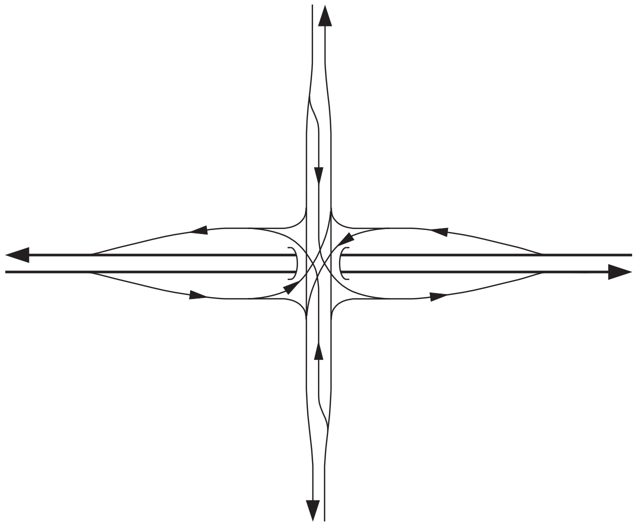
Objectives:
- To increase capacity
- To allow for shorter spacing of slip road connection points

Fig. 48: Diamond with two intersections

The following two diamond systems (Fig. 49 and Fig. 50) have one thing in common, namely that both intersections are combined to form one large partial junction – generally with traffic lights.

In the case of the **diamond with one intersection** (Fig. 49), both partial junctions are merged to form a signal-controlled intersection that has not been expanded. The system has a greater capacity than the solution in Fig. 48 because there is no capacity-reducing crossover of opposite left-turning lanes. The necessary intersection form with the pairs of entry slip roads and exit slip roads can only be constructed economically on motorways with narrow cross-sections.

Wider motorway cross-sections require much more extended intersection designs, resulting in a correspondingly wide bridge. The same applies to cases where the motorway is not carried under the junction, but over it. In this case, the motorway is carried over the extensive intersection.



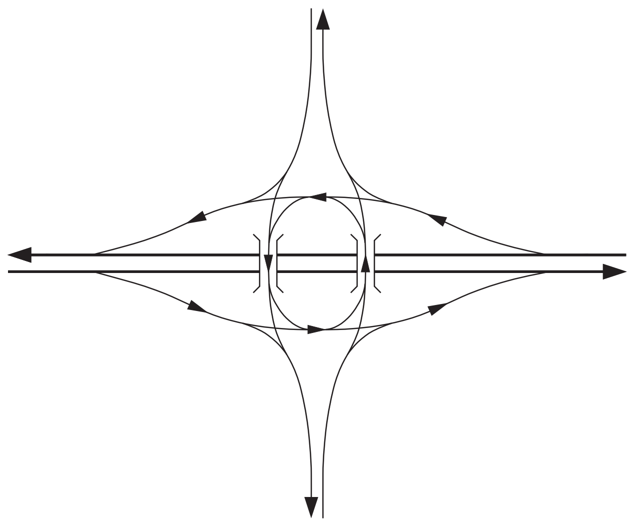
Advantages:
- Favourable in terms of the dynamics of vehicle movement
- Higher capacity than the diamond with two intersections
- Lower land acquisition requirements
- Junction does not extend as far into the subsidiary road as the diamond with two intersections

Disadvantages:
- Must be signal-controlled
- Slip roads in all four quadrants
- Very large grade-separation structure needed for wide motorway cross-sections
- No opportunities for vehicles to turn around

Fig. 49: Diamond with an intersection

As the name indicates, instead of two partial junctions, the **diamond with one intersection that has been expanded in two axes** (Fig. 50) features a single, signal-controlled intersection that has been expanded in two axes. The widening in the motorway axis is the result of the parallel arrangement of the diamond's slip roads. The widening in the second axis necessitates the separation of the subsidiary road into two uni-directional carriageways. This creates a junction system with a high capacity that is capable of coping with high-volume entry streams and exit streams in all directions despite its comparatively low land acquisition requirements and the fact that only two signal phases are necessary (short queuing areas on the exit slip roads as a result of short traffic light cycle times). It is particularly suitable for junctions in restricted spaces with high traffic loads.

Because of the fact that they are not easily understood by drivers and make high demands on directional signing, **special systems** that combine elements of the above-mentioned junctions should only be used in exceptional cases where local conditions preclude the utilization of standard solutions.



Advantages:
- Favourable in terms of the dynamics of vehicle movement
- Very high capacity coupled with short traffic light cycle times (two-phase signal programme)
- Opportunities for vehicles to turn around; favourable for operation and winter maintenance services

Disadvantages:
- Must be signal-controlled
- Slip roads in all four quadrants
- Two bridges

Fig. 50: Diamond with one intersection that has been expanded in two axes

6.3.3.3 Three-leg interchanges

The standard solution for three-leg grade-separated intersections is the trumpet layout. In order to prevent wrong-way driving, the directional traffic streams on the subsidiary road should be structurally separated. If utilizing this layout, a junction system in accordance with Section 6.3.2.2 must be selected, generally the trumpet layout in Fig. 38.

If the road on the subsidiary arm has only one carriageway, a trumpet-layout junction (Fig. 51) must be used. In this system, the exit slip road for right-turning traffic should be straight and meet the motorway feeder road at a right angle. Switching the order of the points where the slip roads leave the subsidiary road (entry slip road upstream of the exit slip road) improves orientation on roads where the directional traffic streams are not separated on the subsidiary road and reduces the likelihood of wrong-way driving. The conditions for utilization in Section 6.3.2.2 also apply here to 'left-facing' and 'right-facing' trumpet variants.

With this system, there is the problem of keeping traffic that is not suitable for motorway travel off the motorway. For this reason, the feeder road should, where possible, be designed as the third arm of a T-junction (similar to the slip roads in the half-cloverleaf) to which the subsidiary road network is connected. A roundabout instead of a T-junction can provide the opportunities for service vehicles to turn around.

Moreover, three-leg junction systems can be developed on the basis of four-leg systems from which the slip roads that are not required have been eliminated. However, these solutions are only expedient in those cases where the subsequent development of the three-leg junction to a four-leg system is intended.

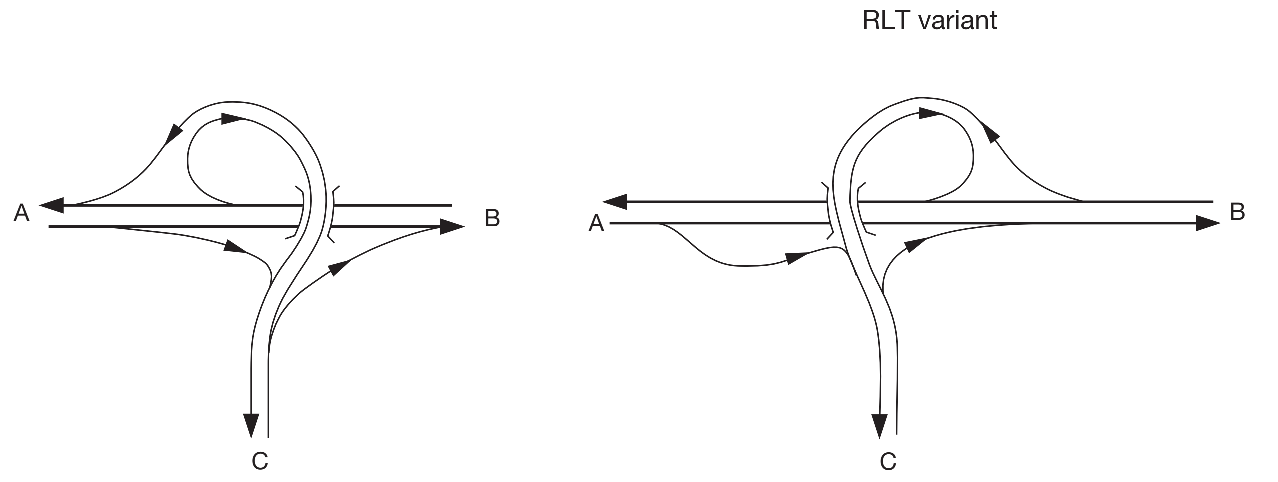
6.4 Junction elements

6.4.1 General remarks

Junction systems comprise a number of different junction elements (see Appendix 8). Such elements include:

- connector roads,
- exits,
- entries, and
- weaving areas.

The characteristic that exerts the greatest influence on the quality of the traffic flow in all junction elements is the number of lanes. When adjusting the number of lanes in individual junction elements to suit the traffic load, the coherence of the entire junction system (including selected connector road cross-sections and exit and entry types) should be verified using a so-called **'lane plan'** in which each lane is depicted as a line. In situations where the spacing between two junctions is less than the minimum spacing requirement outlined in Section 6.2.2, this verification process should include the sections of motorway right up to the next, closely spaced junction.



Advantage: – Expedient in the event of high turning movement A–C
Disadvantages: – The subsidiary road terminates in a connector road
– Relatively high land acquisition requirements (also applies to the RLT variant)
– Wrong-way driving is not fully preventable (also applies to the RLT variant)
– Limited turning opportunities (also applies to the RLT variant)
– One exit slip road is unfavourable in terms of the dynamics of vehicle movement
RLT variant: Right-facing trumpet
Objective: – To adapt the junction to topography
– To adapt the junction to a high turning movement B–C
Disadvantage: – Carriageway ends in a loop (see Section 6.3.2.2)

Fig. 51: Junction system in trumpet form

The basic principles for signing and road marking in the RWBA and the RMS respectively apply.

At three-way interchanges, the following applies to the extremities of the slip road for the third, directly connected arm of the junction: the mainline carriageways on the third arm (i.e. the motorway that begins or ends at that junction) are considered to be slip roads from the last exit upstream of the junction or the first entry downstream of the junction even if the standard cross-section of the open road is applied (Section 6.4.2.2). This definition applies analogously to grade-separated fork junctions provided that fictitious exits and entries are assumed to take the place of the missing connector road connections.

The information on exits and entries on the mainline carriageway in Section 6.2.3 apply analogously to the exits and entries in the connector road system (AR types, ER types) and to the alignment of the mainline connector road carriageway.

If special **maintenance access roads** are necessary to allow service vehicles to turn at junctions, these roads must be made visually different by giving them narrower carriageways, smaller curve radii, and/or by separating them from the slip roads with barriers (see Section 8.9). Maintenance access roads or maintenance access points may only be connected to connector roads at points where visibility is very good.

The following design remarks do not refer to at-grade partial junctions connecting with the subsidiary network at junctions. These at-grade partial junctions shall be planned in accordance with the RAL or the RASt.

6.4.2 Connector roads

6.4.2.1 Connector road classification

There are two kinds of connector road: link roads and slip roads (Appendix 8).

Link roads are used to keep weaving manoeuvres away from the main carriageway (e.g. at cloverleaf interchanges, to observe the 'exit before entry' rule, or between two closely spaced junctions that are combined to create a single complex junction). They are also used to allow vehicles to adapt (i.e. reduce) their speed when moving from the open road to the slip road and help to reduce the frequency of directional signing on the mainline carriageway.

Slip roads are used to carry traffic flows between different mainline carriageways at three-way or four-way interchanges and to carry merging and diverging traffic flows at junctions. Slip roads are subdivided according to connector road group and slip road type.

Roads are allocated to a particular **connector road group** (Fig. 52) according to the relevant junction type: slip roads at three-way or four-way interchanges and link roads (i.e. connector roads that start at an exit and end at an entry) belong to connector road group I (grade separated–grade separated), regardless of whether the exit or entry is on a mainline carriageway (types A or E) or in the connector road system (types AR, ER). Slip roads at junctions (i.e. connector roads that start at an exit and end at an at-grade partial junction on the subsidiary road or the other way around) belong to connector road group II (grade separated–at-grade).

Slip roads are allocated to a particular **slip road type** according to the horizontal alignment of the slip road: direct, semi-direct, or indirect (Fig. 52). Direct and indirect slip roads are further subdivided into the categories 'adapted' and 'unadapted'; semi-direct slip roads are further subdivided into the categories 'fast' and 'slower'.

In the case of the cloverleaf interchange, the selection of the respective slip road (adapted/compressed/elongated) depends not only on the design class, but also on local conditions (available land, topography, longitudinal gradient of the mainline carriageway) and the desired traffic flow quality on the slip road (Section 6.4.2.3). While unadapted, circular loops are preferable for EKA 1 motorways, adapted loops should be used for EKA 2 and EKA 3 motorways.

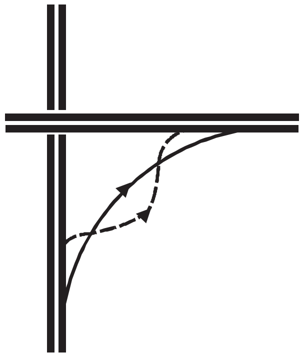
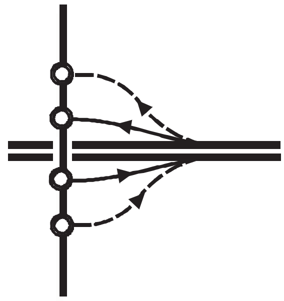
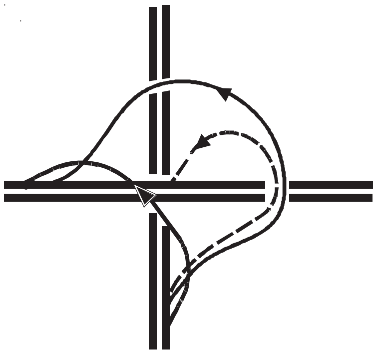
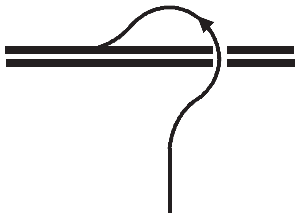
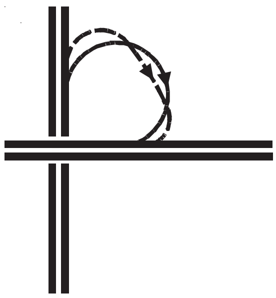
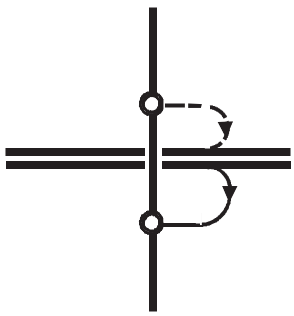
No slip roads are used in built-up areas and, in the case of connector road group II, may not contain any T-junctions or crossings ahead of the defined junction to the subsidiary network. There should be no non motorway-related land use within the junction that needs to be connected to the network (i.e. no structures that are surrounded by slip roads). The only exceptions to this rule are facilities belonging to the road operation service and the motorway police.

6.4.2.2 Connector road cross-sections and the situations in which they are used

The number of lanes on a connector road depends on the connector road traffic volume. Application parameters can only be provided for sections of connector road where no weaving occurs. The capacity of the weaving areas on the connector road system should be checked on a case-by-case basis.

In the case of long connector roads, especially in the case of semi-direct slip roads and long link roads, the ability to overtake slow vehicles is an additional criterion when specifying the number of lanes. The length of a connector road is the distance measured from the tip of the nose of the exit to the tip of the nose of the entry, whereby prominent exits and entries should be used for each traffic stream under consideration.

The provision of hard shoulders on connector roads is restricted to connector road group I and only necessary in those cases where the cross-section of the connector road does not already allow for the overtaking of a stalled vehicle without obstructing traffic for other reasons (lane widening, two lanes only because the connector road is longer). For reasons of traffic safety, semi-direct or indirect slip roads in tunnels must always have a cross-section with a hard shoulder.

Slip road type	Connector road group I (grade separated – grade separated)	Connector road group II (grade separated – at-grade)
Direct	——— $60 \leq V_{Rampe} \leq 80$ - - - - - $50 \leq V_{Rampe} \leq 60$ 	——— $V_{Rampe} \geq 80$ - - - - - - $40 \leq V_{Rampe} \leq 80$ 
Semi-direct	——— $60 \leq V_{Rampe} \leq 70$ - - - - - $40 \leq V_{Rampe} \leq 60$ 	——— $40 \leq V_{Rampe} \leq 60$ 
Indirect	——— $40 \leq V_{Rampe} \leq 50$ - - - - - $30 \leq V_{Rampe} \leq 50$ (entry) - - - - - $40 \leq V_{Rampe} \leq 50$ (exit) 	——— $V_{Rampe} \geq 40$ - - - - - $30 \leq V_{Rampe} \leq 40$ 

Legend: _________ V_{Rampe} for unadapted alignment (fast alignment, EKA 1)
- - - - - - - - V_{Rampe} for adapted alignment (slower alignment, EKA 2 und 3)

Fig. 52: Slip road types and connector road groups with recommended radius speeds (V_{Rampe} [km/h])

The hard shoulder can be omitted from the weaving areas of link roads on EKA 3 motorways where space is at a premium (Section 6.4.5.2).

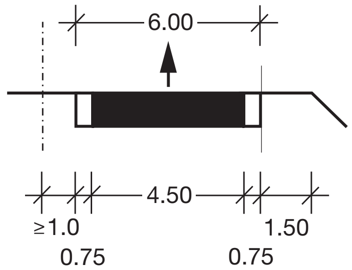
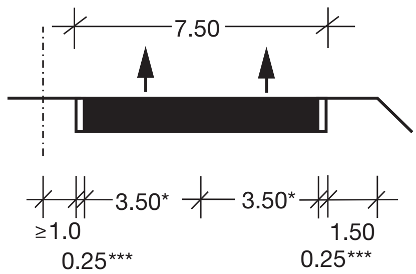
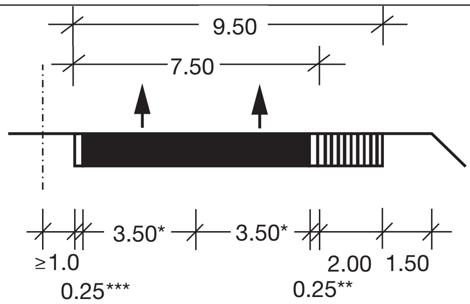
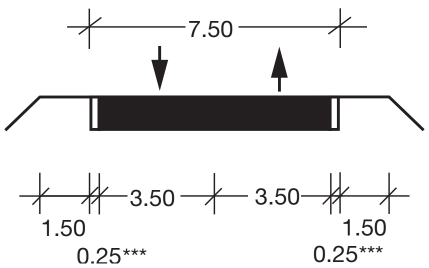
The **standard cross-sections for connector roads** are given in Fig. 53. In exceptional cases the narrower lane width of B = 3.25 m can be used on lanes marked with an asterisk (*) at junctions on EKA 3 motorways where space is at a premium.

In individual cases, the following **conditions** apply:

Connector road group I (three-way and four-way interchanges)

– The **connector road cross-section Q 1** (single lane) is used on sections of all connector road types (both link roads and slip roads) where no weaving occurs as long as the connector road traffic volume does not exceed 1,350 vehicles/h and the length of the connector road does not exceed 500 m. The 4.50-m wide lane can, if necessary, also be marked asymmetrically.

– The **connector road cross-section Q 2** (two lanes, no hard shoulder) is used on sections of all connector road types (both link roads and slip roads) where no weaving occurs as long as the connector road traffic volume does not exceed 1,350 vehicles/h, but where the length of the connector road exceeds 500 m. It is also used for two-lane weaving areas on connector roads without a hard shoulder.

<table>
<tr><th></th><th></th><th>Areas of application</th></tr>
<tr><td>Q 1</td><td>
</td><td>In connector road group I:
$q_{Rampe} \leq$ 1,350 vehicles/h and
$l_{Rampe} \leq$ 500 m
In connector road group II:
Separate exit and entry slip roads that run parallel to each other over the distance
$l_{Parallelführung} \leq$ 125 m</td></tr>
<tr><td>Q 2</td><td>
</td><td>In connector road group I:
$q_{Rampe} \leq$ 1,350 vehicles/h and
l_{Rampe} > 500 m
Also for two-lane weaving areas without hard shoulders
In connector road group II:
q_{Rampe} > 1,350 vehicles/h</td></tr>
<tr><td>Q 3</td><td>
</td><td>Only in connector road group I:
q_{Rampe} > 1,350 vehicles/h
Also for two-lane weaving areas with hard shoulders</td></tr>
<tr><td>Q 4</td><td>
</td><td>Only in connector road group II:
Combined exit and entry slip roads that run parallel to each other over the distance
$l_{Parallelführung}$ > 125 m</td></tr>
</table>

*) A narrowing of the lane width to 3.25 m is permissible for EKA 3 and elongated alignment.
**) The markings (‚broad line‘) are drawn in such a way that they reduce the width of the hard shoulder, not the lane.
***) The hardstrip on bridges is 0.50 m wide.

Fig. 53: Connector road cross-sections and the situations in which they are used (dimensions in [m])

– The **connector road cross-section Q 3** (two lanes with hard shoulder) is used on sections of all connector road types (both link roads and slip roads) where the connector road traffic volume exceeds 1,350 vehicles/h. It is also used for two-lane weaving areas on connector roads with hard shoulders.
– As an exception to this rule, those slip roads at three-way interchanges (Section 6.3.2.2) that start directly on the through carriageway (i.e. on a section without junctions or interchanges) or lead into them are provided with the standard cross-section of the relevant mainline carriageway instead of a connector road cross-section.
– The width of the hard shoulder (2.50 m) is retained in the area around entries and exits.
– The markings ('broad line') delineating the hardstrip are drawn in such a way that they reduce the width of the hard shoulder.

Long link roads at complex junctions that have a two-lane cross-section (Q 2 or Q 3) in those areas where no weaving occurs are provided with an additional weaving lane in those areas where weaving occurs. If the necessary width is not available when improving the road, the weaving lane takes precedence over the two-lane layout of the link road.

In connector road group I, the connector road shall physically be provided with the same cross-section as the cross-section on the mainline carriageway at the tip of the nose in the exit and entry areas. At the entry area for cross-sections Q 1 and Q 2, the cross-section shall only be narrowed using pavement markings.

Connector road group II (junctions)

Opposing exit and entry slip roads with different cross-sections are permissible at junctions as long as they are separated by a central reserve measuring at least 2 m in width.

Single-carriageways for opposing traffic streams should be used at junctions if they constitute a less expensive solution than having separate exit and entry slip roads. The criteria are the length of the section over which the streams run parallel (measured between the adjacent taper points) and the compatibility of the vertical alignments in both directions.

– As a rule, the **connector road cross-section Q 1** (single lane) is used for separate exit and entry slip roads, as long as the length of the section over which the streams run parallel does not exceed 125 m.
– As an exception to this rule, it may be necessary to use **connector road cross-section Q 2** (two-lane, without hard shoulder) on exit slip roads if the traffic volume on each directional slip road requires more than one lane or if two lanes would help avoid queues stretching back to the motorway (e.g. queuing area upstream of at-grade partial junctions).
– **Connector road cross-section Q 4** (two-lane carriageway with opposing traffic streams) is used in those cases where the exit and entry slip road are combined over a distance of 125 m and no other cross-section is needed for traffic reasons.

The exit and entry areas in connector road group II always have cross-section Q 1 or Q 2 at the tip of the nose.

6.4.2.3 Connector road design elements

Connector road design elements are more restricted than design elements on the through carriageway because of the fact that vehicles are meant to travel more slowly on connector roads. Nevertheless, adequate sight distances to directional signing and that will allow vehicles to stop shall be observed. The recognisability of smaller road elements that require a considerable reduction in speed when driving on the connector road take precedence over the visual appearance of the roadway.

The dimensions of the connector road design elements are specified in accordance with the desired design standard on the basis of the connector road speed in wet conditions in accordance with Table 21.

In individual cases where entry, exit, and weaving areas are experiencing heavy traffic loads and for reasons of safety and the quality of traffic flow, it may be necessary to introduce speed limits in consultation with the traffic authorities.

The minimum length of a slip road is determined by the slip road type, the necessary development length, the legibility distance for directional signing, the necessity to ensure adequate spatial and temporal spacing of decision points, channelization, and any necessary queuing area lanes upstream of the at-grade partial junction at points of access. In individual cases, designers should investigate the use of storage space monitoring in conjunction with traffic lights at at-grade partial junctions.

The **straight** can be used without restriction in horizontal alignment. Parallel connector roads (with the exception of link roads) should not be longer than 300 m to ensure that they do no create the impression of being a separate, parallel road. Exit slip roads at junctions should be elongated to such an extent, both in the horizontal and the vertical plane before they reach the subsidiary road, that a legibility distance of at least 50 m is ensured ahead of directional signing. Otherwise advance direction signs will have to be erected along the exit slip road.

Table 21 contains an overview of the **limiting values for other road elements.** The upper part of the table contains the parameters with speed-related, varying limiting values; the lower part of the table contains the parameters with uniform limiting values for all connector roads. The upper part of the table shall be applied individually to each connector road. The initial variable is the connector road speed because it determines the characteristics of the connector road better than the design class. The upper part of the table is most important for slip

Table 21: Parameter limits for connector road design elements

Connector road speed	V	[km/h]	30	40	50	60	70	80
Crown radius of the slip road	min R	[m]	30	50	80	125	180	250
Minimum crest diameter	min H_K	[m]	1,000	1,500	2,000	2,800	3,000	3,500
Minimum sag diameter	min H_W	[m]	500	750	1,000	1,400	2,000	2,600
Stopping sight distance*)	S_h	[m]	30	40	55	75	100	115
Longitudinal gradient limiting value	max s	[%] (ascending gradient)	+ 6.0					
	min s	[%] (descending gradient)	– 7.0					
Minimum crossfall outside superelevation areas	min q	[%]	2.5					
Maximum crossfall	max q	[%]	6.0					
Minimum relative grade	min Δs	[%]	0.1 · a a [m]: Distance from the 'Axis of rotation' to the edge of carriageway					
Maximum incline	max p	[%]	9.0					

*) values rounded off in accordance with Appendix 7

roads because they can largely be designed separately. On the other hand, the horizontal and vertical alignment of the link (distributor) road is largely determined by the parallel mainline carriageway, which means that there is very little freedom in terms of moving the road elements.

The crown radius of a slip road is specified within tight boundaries by the selected junction system and the resulting slip road type. The line of reference for the radius in the inner edge of the carriageway.

The remaining scope, as defined by the connector road speeds given in Fig. 52, should be utilized in accordance with the various design classes. The lower the design class of the motorways or subsidiary road being connected by the connector road, the more frequently the adapted slip road types and the less frequently the fast slip road types should be used.

Clothoids with the parameter, A, which is between R/3 and R (R/3 ≤ A ≤ R), shall be used as **transition curves**. Designers should aim for the smallest possible clothoid parameter for the curve around the tip of the nose in order to ensure that drivers can recognize the curve radius that follows at the earliest possible stage. Clothoid parameter A approximately equal to R, on the other hand, is often necessary for loop-shaped exit slip roads with main curve radii of between 40 m and 60 m in order to ensure that the superelevation of the transition curve can be developed. In the interest of ensuring that the tip of the nose is recognized, designers shall aim for an angle of departure of at least 12 gon (10.8°). This value may make it necessary to pivot link roads. Smaller values are permissible, but the minimum value of 6 gon (5.4°) must be observed. Entry slip roads shall be connected to the through lane using the smallest possible entry angle (3–5 gon or 3–5°).

As far as **vertical alignment** is concerned, the limiting values for longitudinal gradients are 6 % for the ascending gradient and -7 % for the descending gradient. The longitudinal gradients should be within these limits. In cases where the longitudinal gradient of the roads being connected is steep and in cases where there is a so-called 'extended longitudinal gradient', these limiting values may be exceeded as long as the maximum incline of 9 % is observed. For connector roads in tunnels, a maximum longitudinal gradient of 4 % (see Section 8.5) shall apply.

Changes in longitudinal gradient shall be curved according to the same principles that apply on the open road. The **minimum curve diameters** may be reduced if evidence can be provided in the three-dimensional design that the slip road guarantees the necessary stopping sight distance.

All **carriageways** for all slip road types shall be inclined to one side. The minimum crossfall outside the superelevation development areas is 2.5 %, the maximum crossfall 6 %. The **crossfall** in curves is to the inner edge of the curve (Fig. 54). In exceptional cases, a crossfall of 2.5 % to the outer edge of the carriageway on a pivoted link road is permissible in order to avoid areas where the crossfall passes through zero in a reverse curve as long as the reverse curve has a radius of R greater than or equal to 1,000 m.

The **superelevation area** between the connector road sections with different crossfalls shall be designed in accordance with Section 5.6. Where possible, the superelevation should be completed within the transition curve. Either the centreline of the road or the edge of the carriageway can be used as the axis of rotation for the superelevation of the surface of the carriageway. There is no need to observe a maximum superelevation. Table 21 gives the minimum relative grade required to ensure drainage.

Widening of the carriageway may become necessary because the rear wheels of a vehicle take a tighter curve than the front wheels when travelling in a curve. This

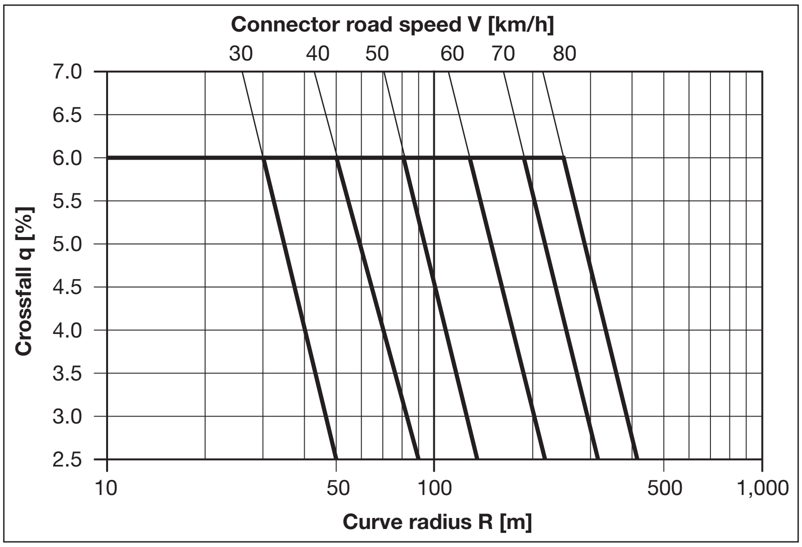


Fig. 54: Crossfalls for connector roads in relation to connector road speed (Table 21) and the curve radius

means that a wider lane is needed in tight connector road curves than is the case on the straight (Fig. 55). This is particularly the case with curve radii of R less than 150 m.

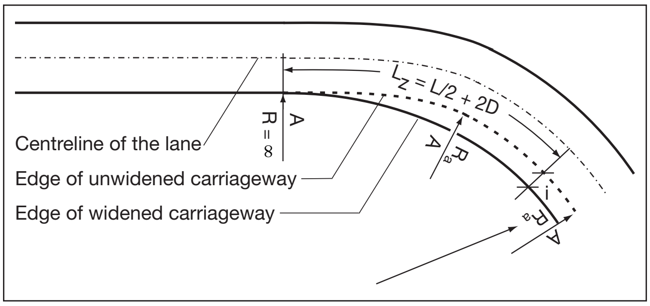


Fig. 55: Widening of the carriageway in tight curves in situations where a straight is followed by a clothoid and a circular curve

The necessary widening of the carriageway for n lanes in a circular curve is calculated using equation 17. The widening dimension is distributed evenly over both lanes.

$$i = n \cdot (R_a - \sqrt{(R_a^2 - D^2)}) \qquad (17)$$

D [m] = Wheel base and front overhang (for an articulated truck: D = 11.90 m)

i [m] = widening of the carriageway

n [–] = Number of through lanes

R_a [m] = Radius of the circular curve to the outer edge

L [m] = Length of the transition curve

L_z [m] = Distance until the widening dimension i has been reached

Experience has shown that in the case of slip road type Q 1, the available paved width is sufficient to accommodate the additional space needed by the rear wheels of a vehicle. For this reason, the widening of the carriageway is generally only necessary for slip roads with two lanes (slip road types Q 2, Q 3, and Q 4).

The **incline** is limited to a maximum of p = 9 %. The minimum incline of 0.5 % must also be observed in the connector road system.

Finally, as is the case on the open road, evidence must be provided using the three-dimensional connector road design that the available stopping sight distance is not less than the **necessary stopping sight distance** at any point on the connector road. If necessary, the parameters of the elements of alignment, especially the crest diameter, shall be increased. The necessary stopping sight distance depends on the design speed specified for the connector road, which is given in Fig. 52, and the longitudinal gradient. Details of the necessary stopping sight distance are given in Table 21 and in Appendix 7 for a variety of longitudinal gradient classes. Interim values shall be interpolated linearly. If necessary, the introduction of a speed limit to ensure that the connector road speed is observed should be considered.

6.4.3 Exits

6.4.3.1 General layout of exit areas

In addition to the function of the exit area as a deceleration lane for vehicles leaving the mainline, the factors that have the greatest influence on the layout of the exit areas are recognisability and capacity. For this reason, exits must always be created with parallel diverging lanes.

Diverging lanes shall be the same width as the mainline lane running directly alongside it.

The hardstrip shall be 0.50 m wide.

As a rule, the length of the diverging lane shall be in accordance with Section 6.4.3.2 and Table 22. Diverging lanes that are longer than the specified lengths can be expedient in the following exceptional situations:

– if the mainline carriageway has more than two lanes,
– if the proportion of heavy vehicle traffic is very high, or
– if the diverging lane is the approach to a junction with high traffic load.

The diverging lane should only be created with a hard shoulder if the slip road diverging from the mainline has a cross-section with a hard shoulder. In this case the hard shoulder should be 2.50 m wide. In all other cases, it is sufficient for all protective devices alongside the diverging lane to be moved back far enough to allow vehicles to pull up on the verge in an emergency. In this case, the width of the verge – which must be designed to be stable – to the protective device should be 2.00 m.

Table 22: Values for the dimensions l_A and l_Z for exit type plans (dimensions given in [m])

Dimension	Exit type	EKA 1 / EKA 2	EKA 3
l_A	All A types	250	150
	AR 1, AR 3 / 4 (Q 2)	150	100
	AR 1*	–	100
	AR 3 / 4 (Q 3)	200	125
l_Z	All types*	60	30

* Exception A5 ≥ 3 · l_Z (due to the driving dynamics)

In the vicinity of structures, the taper length can be reduced to 30 m if this reduces the cost of the structure.

The layout of the beginning of the marked area influences the recognisability of the exit and, therefore, road safety. Small slip road radii in the exit area should be made clear to drivers by dense spacing of marker posts and directional signs at the outer edge of the curve. Ghost (painted) islands are recommended at the tip of the nose (gore area). Designers should make sure that this island is visible at night. This painted island is all the more important if there is a ridge in the cross-section between the mainline carriageway and the diverging lane.

The back of the painted area shall be 1.50 m wide. In exceptional cases, it should only be curved (R = 0.75 m) if it is surrounded by kerbs. The area behind the painted area of the nose should, if possible, be level with the carriageway and be kept free of traffic signs, protective devices, and other obstacles.

In addition to the design layout, directional signing has a considerable influence on the function and capacity of an exit. It also influences the necessary length of each exit opening. The regulations of the RWBA apply when specifying the minimum distance between consecutive exits on main carriageways and connector roads (Section 6.2.2).

6.4.3.2 Exit types and the situations in which they are used

The layout of exit areas should be as uniform as possible. To this end, standardized exit types should be used. As a rule, the exit types on mainline carriageways and connector roads described below can be used for all motorway design classes.

Fig. 56 a and Fig. 56 b show the **exit types that are suitable for use on mainline carriageways (A types)**. These figures also include information on the cross-sections of the connector roads that can be connected to these exit types and the minimum spacing requirements to consecutive exits on the connector road that may be needed for orientation or for lane changes. All of these exit types can also be used accordingly on three- or four-lane mainline carriageways.

Fig. 57 shows the **exit types for the connector road system (AR types)** and contains information on the cross-sections of the connector roads that can be connected to these exit types.

At junctions where EKA 3 motorways intersect, the **exit type AR* for exits on connector roads** (Fig. 58) can also be used to better adapt to the traffic demand for that exit.

The dimensions l_A and l_Z, which are specified in the exit type plans (Fig. 56 to Fig. 58), vary according to design class and exit type and are given in Table 22.

In situations where diverging lane lengths in excess of those given in Table 22 are to be used as a sorting area at the approach to a junction with a high traffic load, the length of the diverging lane is based on the queues or the diverging traffic flows that can be expected to occur. A measure such as this can be necessary, in particular in situations where the level of service (D) or better cannot be guaranteed on the mainline carriageway or on the exit slip road.

The **situations in which the exit types are used** are determined by their capacity in accordance with the HBS, the potential required reduction of the number of lanes after the exit, the number of destinations that can be reached using this exit, and the distance to the next diverge.

Exit type A 1 is the standard exit type layout for junctions where the number of lanes on the mainline carriageway remains unchanged and the hourly volume of traffic leaving the main carriageway does not exceed 1,350 vehicles. It is generally combined with connector road cross-section Q 1. In the case of long connector roads belonging to connector road group I, it can also be combined with connector road cross-section Q 2. In these cases, the transition area between the exit and the slip road shall be designed in such a way that two lanes are only available downstream of the painted island.

As an alternative to exit type A 1, **exit type A 2** can be used in combination with the connector road cross-section Q 2 for hourly exit traffic flows of less than 1,350 vehicles for long slip roads (connector road group I).

If the hourly exit traffic flow exceeds 1,350 vehicles, exit type A 2 shall be used for connector roads belonging to connector road group I with connector road cross-section Q 3 or the standard cross-section of a carriageway.

In both cases, it is important to make sure that no diverge follows, or if a diverge is necessary, that it is positioned at least 250 m downstream and that the number of lanes along the mainline carriageway does not change.

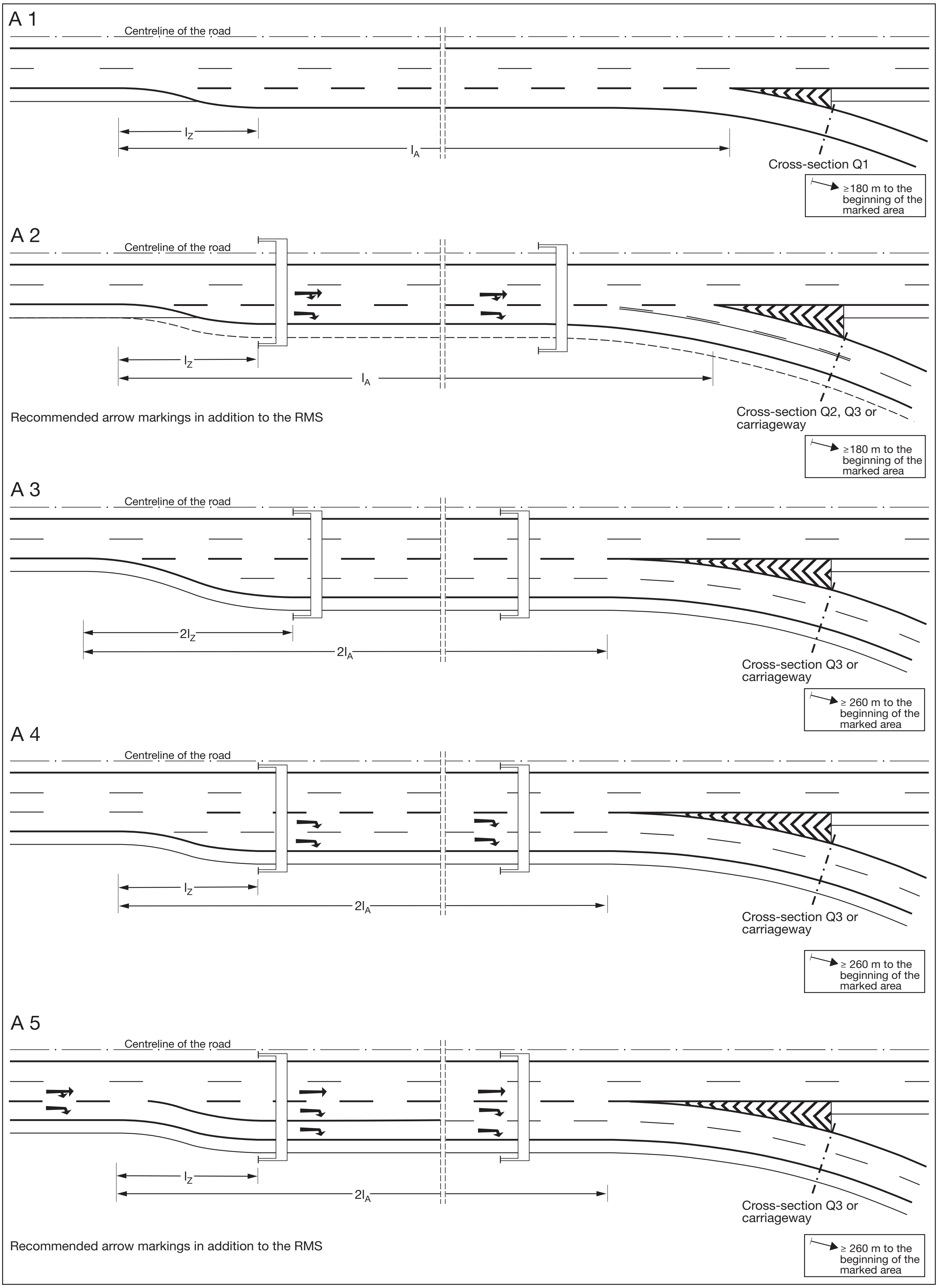


Fig. 56 a: Types of exits on mainline carriageways

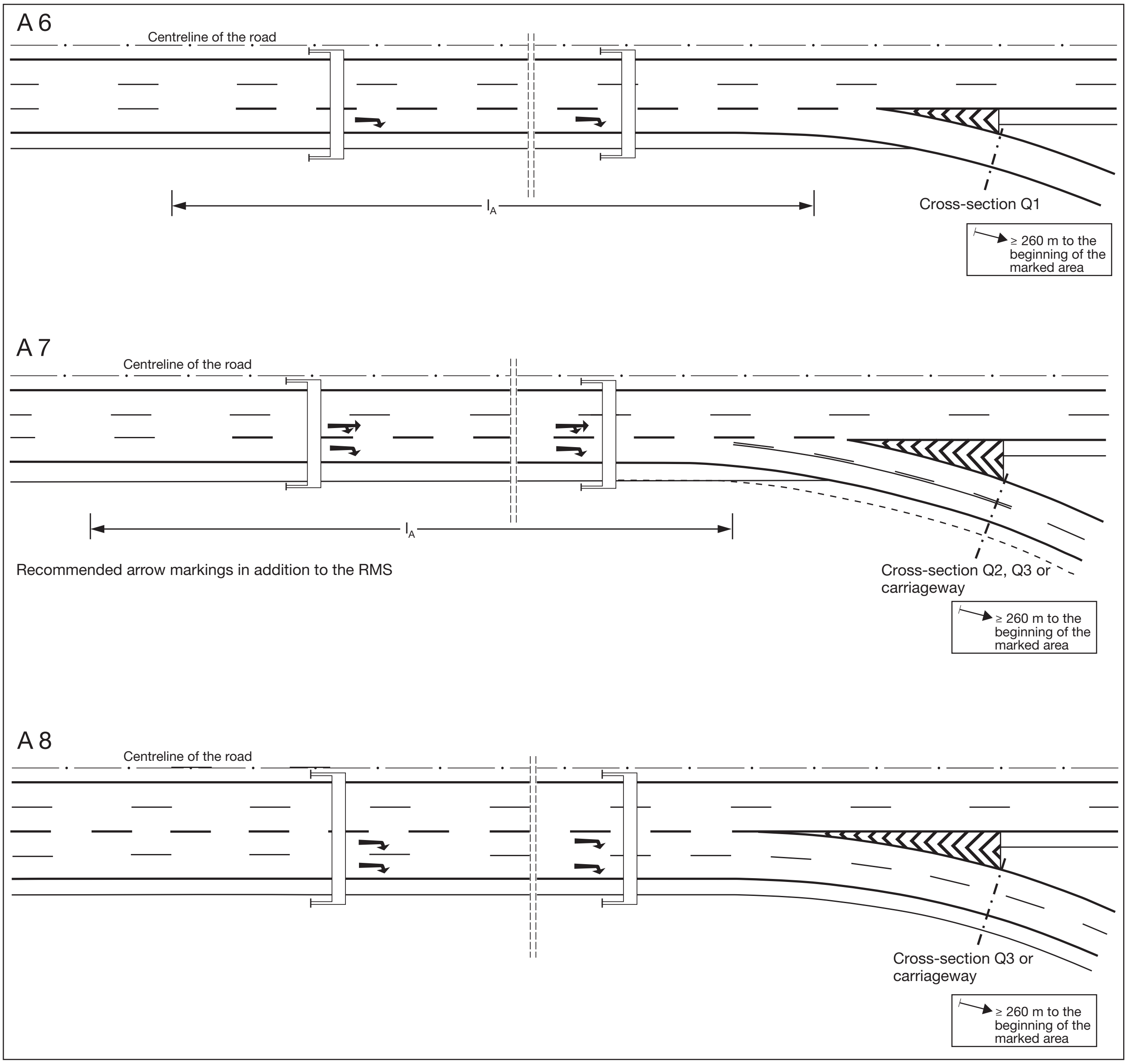


Fig. 56 b: Types of exits on mainline carriageways

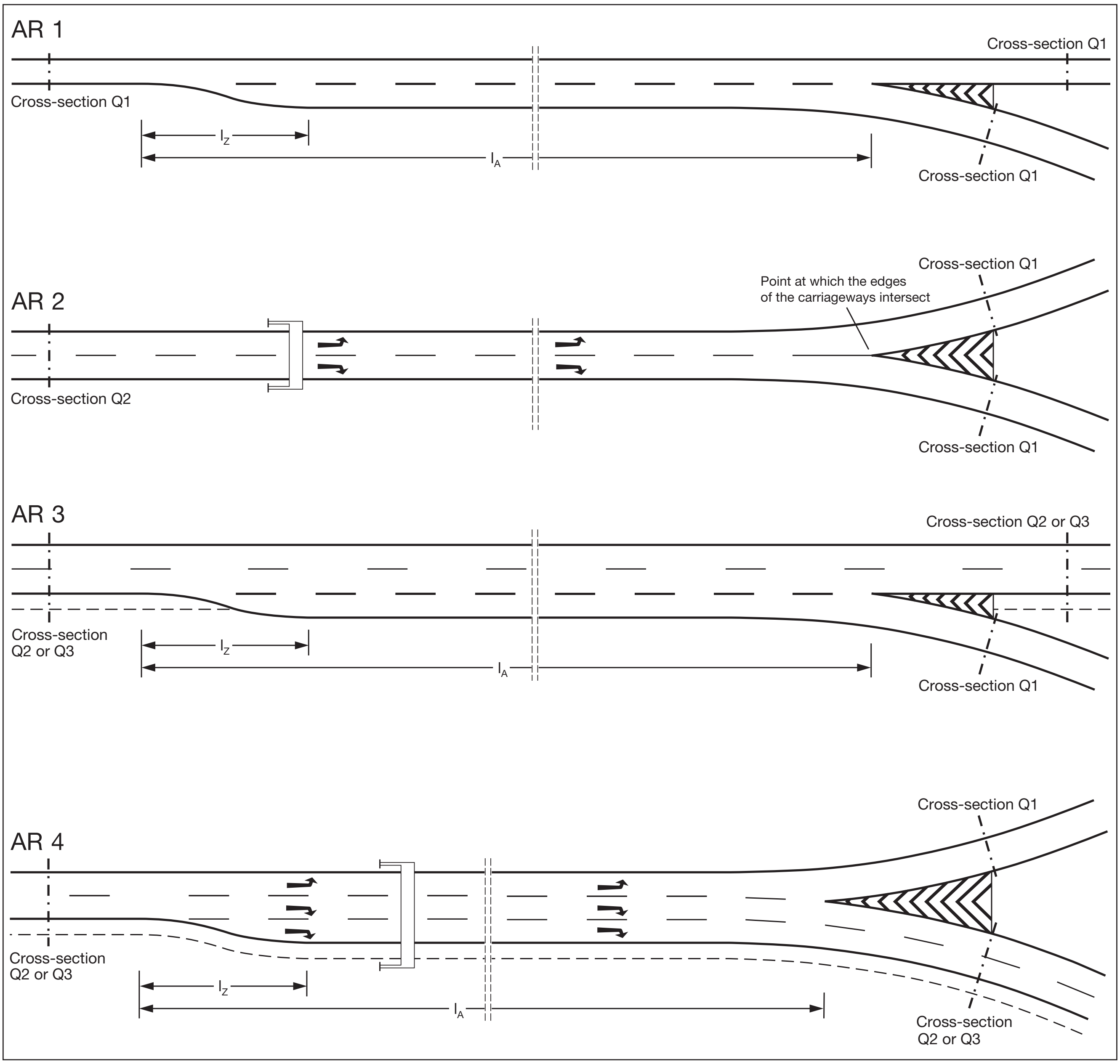


Fig. 57: Types of exits in the connector road system

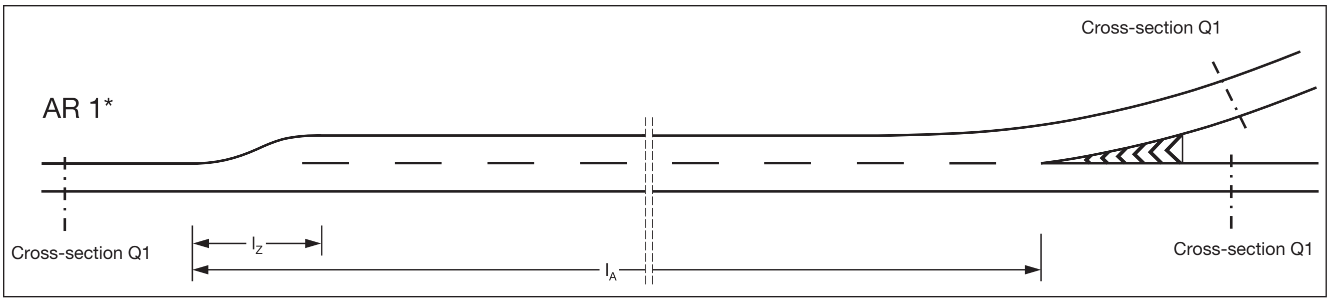


Fig. 58: Additional exit type for the connector road system at urban motorway junctions (EKA 3)

In connector road group II, a combination of exit type A 2 and connector road cross-section Q 2 shall be used.

The capacity of this exit type can be achieved more easily if the exit's two lanes are clearly marked (arrows on the pavement surface) and indicated using directional signing. The exit slip road should not curve too tightly immediately after the painted island to avoid excessive delays in the right-hand lane on the mainline carriageway.

Exit type A 3 shall be used in those situations where the hourly exit traffic flow exceeds 2,300 vehicles and the number of lanes on the mainline carriageway does not change. The exit type A 3 can be combined with the two-lane connector road cross-section Q 3 or the standard cross-section of a two-lane carriageway.

Exit type A 4 shall be used in those situations where the hourly exit traffic flow exceeds 1,350 vehicles, the number of lanes on the mainline carriageway is reduced by one lane, and traffic on the main carriageway needs to be channelled for two different exit destinations. In this case, the dropped lane becomes the left-hand lane of the slip road. A diverging lane on the right becomes the right-hand lane of the slip road. Exit type A 4 can be combined with the two-lane connector road cross-section Q 3 or the standard cross-section of a two-lane carriageway.

Exit type A 5 shall be used instead of exit type A 4 in those situations where it is not necessary to channel traffic on the main carriageway for two different exit destinations. The exit's two lanes shall be clearly marked and signed. Exit type A 5 can be combined with the two-lane connector road cross-section Q 3 or the standard cross-section of a two-lane carriageway.

Exit type A 6 is used when the cross-section of the mainline carriageway is reduced by one lane and the hourly exit traffic flow does not exceed 1,350 vehicles. It is generally combined with connector road cross-section Q 1. In the case of long slip roads belonging to connector road group I, it can also be combined with connector road cross-section Q 2. In these cases, the transition area between the exit and the slip road shall be designed in such a way that two lanes are only available downstream of the painted island.

Exit type A 7 in Fig. 57 is a special solution that is used when improving existing motorways. Otherwise, this exit type can be used in the same situations as exit type A 5. The exit slip road should not curve too tightly immediately after the painted island to avoid excessive delays in the right-hand lane on the mainline carriageway.

Exit type A 8 is used when two lanes with similar traffic streams have to be dropped on a four-lane mainline carriageway. In this case, the exit slip road has the cross-section Q 3 or the standard cross-section of a two-lane carriageway.

Exit type AR 1 is used in situations where both slip roads continue with one lane each (cross-section Q 1). In the area where the two lanes run parallel to one another (diverging area), the cross-section Q 2 can be used as an alternative to gaining two connector road cross-sections Q 1. In this case, the lanes and the edge of the carriageway must be tapered in such a way as to create a visually pleasing solution.

Exit type AR 1* is the mirror image of the exit type AR 1 and is used on EKA 3 motorways with similar traffic demand.

Exit type AR 2 can be used in those situations where the distance to a previous exit exceeds the 500-m limit or if the system is such that the diverge of the connector road makes sense (e.g. in the case of a pivoted link road).

Exit type AR 3 shall be used in situations where a short, low-traffic load connector road (cross-section Q 1) diverges from a long or high-load connector road (cross-section Q 2 or Q 3).

Exit type AR 4 shall be used in situations where the heavier traffic stream continues on to the right.

The function of exit types with two-lane exits is largely determined by the use of lanes in the sorting area (before the exit). If the distribution of traffic load between the lanes around the diverge area is uneven, the use of lane-specific variable message signs (Section 7.9) should be considered in addition to directional signing in individual cases.

Regardless of the exit type situations outlined above, the quality of the traffic flow in the elements of the grade-separated intersection shall be checked in accordance with the HBS.

Table 23: Application parameters for exit types on mainline carriageways

Distance to the next diverge	Number of lanes on the mainline carriageway upstream/downstream of the exit	Traffic flow at the exit in vehicles/h		
		≤ 1,350	≤ 2,300	> 2,300
≥ 250 m (or no other diverge needed)	2/2, 3/3, 4/4	A 1, A 2	A 2	A 3
	3/2, 4/3	A 6, A 7	A 5	
	4/2	–	A 8	
< 250 m	2/2, 3/3, 4/4	A 1	A 3	
	3/2, 4/3	A 6	A 4	
	4/2	–	A 8	

6.4.4 Entries

6.4.4.1 General layout of entry areas

Entries must always be created with parallel merging lanes. The speed difference between the merging and through traffic should be as small as possible.

Merging lanes shall be the same width as the mainline lane running directly alongside it.

The hardstrip shall be 0.50 m wide.

As a rule, the length of the merging lane shall be in accordance with Section 6.4.4.2 and Table 24. For entries where the longitudinal gradient of the merging connector road is different from that of the mainline carriageway ('extended longitudinal gradient'), longer merging lanes may be necessary. This is particularly the case where the mainline carriageway has a steeper ascending gradient than the slip road. Evidence of the required length of the entry shall be provided by the design test vehicle in accordance with the HBS. Merging lanes that are longer than the specified lengths can be expedient if the proportion of heavy vehicle traffic on the mainline carriageway is very high, particularly on ascending gradients.

Table 24: Values for the dimensions l_E and l_Z for entry type plans

Dimension	Entry type	EKA 1 / EKA 2	EKA 3
l_E [m]	All E and E*) types All EE types	250*)	150
	ER 1, ER 4, ER 3	150	100
l_Z [m]	All types	60	30

*) if necessary, extend length on ascending gradients (where s > 4.0 % or traffic engineering evidence in accordance with Section 8.1)

The merging lane should only be created with a hard shoulder if the slip road merging with the mainline has a cross-section with a hard shoulder. In this case it should be 2.50 m wide. In all other cases, it is sufficient for all protective devices alongside the merging lane to be moved back far enough to allow vehicles to stop on the verge in an emergency. In this case, the width of the verge – which must be designed to be stable – to the protective device should be 2.00 m.

The layout of the end of the entry nose influences the visual clarity of the entry. For this reason, the end of the entry nose shall be kept clear of any growth or structure that would obstruct the drivers' line of vision. Designers shall maintain the sight triangle for approach visibility. The edges of the nose and the painted area (ghost island) must be geometrically designed in such a way that merging vehicles are parallel with the mainline carriageway as soon as possible (to ensure rear-view mirror visibility).

The end of the entry nose shall be 1.50 m wide. In exceptional cases, it should only be curved (r = 0.75 m) if it is surrounded by kerbs.

If, in exceptional cases, there is no hard shoulder on the mainline carriageway of an EKA 3 motorway, a hard shoulder should be constructed over a distance of approximately 150 m at the end of the merging lane.

6.4.4.2 Entry types and the situations in which they are used

The layout of entry areas should be as uniform as possible. To this end, standardized entry types should be used. The entry types for mainline carriageways and slip roads outlined below can be used on all motorway design classes.

Fig. 59 shows the **entry types that are suitable for use on mainline carriageways (E types)**. These figures also include information on the cross-sections of the connector roads that can be connected to these entries. These entry types can also be used appropriately on three- or four-lane mainline carriageways.

Fig. 60 shows **EE-type entries for consecutive entries** (double entries). These entry types shall be used in those situations where the slip road flows have to merge separately with the mainline carriageway for capacity reasons. Standard entry types in accordance with the application parameters shall be used for each individual entry. The spacing distances between the two entries should not fall below the distances given in Fig. 60.

E*-type entries for entries on mainline carriageways, which are shown in Fig. 61, can also be used on EKA 3 motorways.

Fig. 62 shows the **entry types for the connector road system (ER types)** and information on the cross-sections of the connector roads that can be connected to them.

The dimensions IE and IZ, which are specified in the entry type plans (Fig. 59 to Fig. 62), vary according to design class and exit type and are given in Table 24.

The **situations in which the entry types** are used are determined by the traffic loads across the cross-section of the connected slip roads and the mainline carriageway downstream of the entry and by the design class.

Entry type E 1 is the standard entry type layout for junctions. A painted island is used to taper the single-lane connector road (cross-section Q 1) to the width of the through lane before the end of the nose is reached.

Entry type E 2 shall be used in those situations where the connector road cross-section Q 2 is selected. A painted island on the right-hand side is used to taper the two-lane connector road cross-section to a single lane before the end of the nose is reached in order to ensure both single-lane merging and the parallel running of merging and through traffic at the earliest possible stage. In situations where there are crests and curves at the end of the connector road area, it may be necessary to move the lane drop far enough ahead to make sure that the tapering can be recognized in good

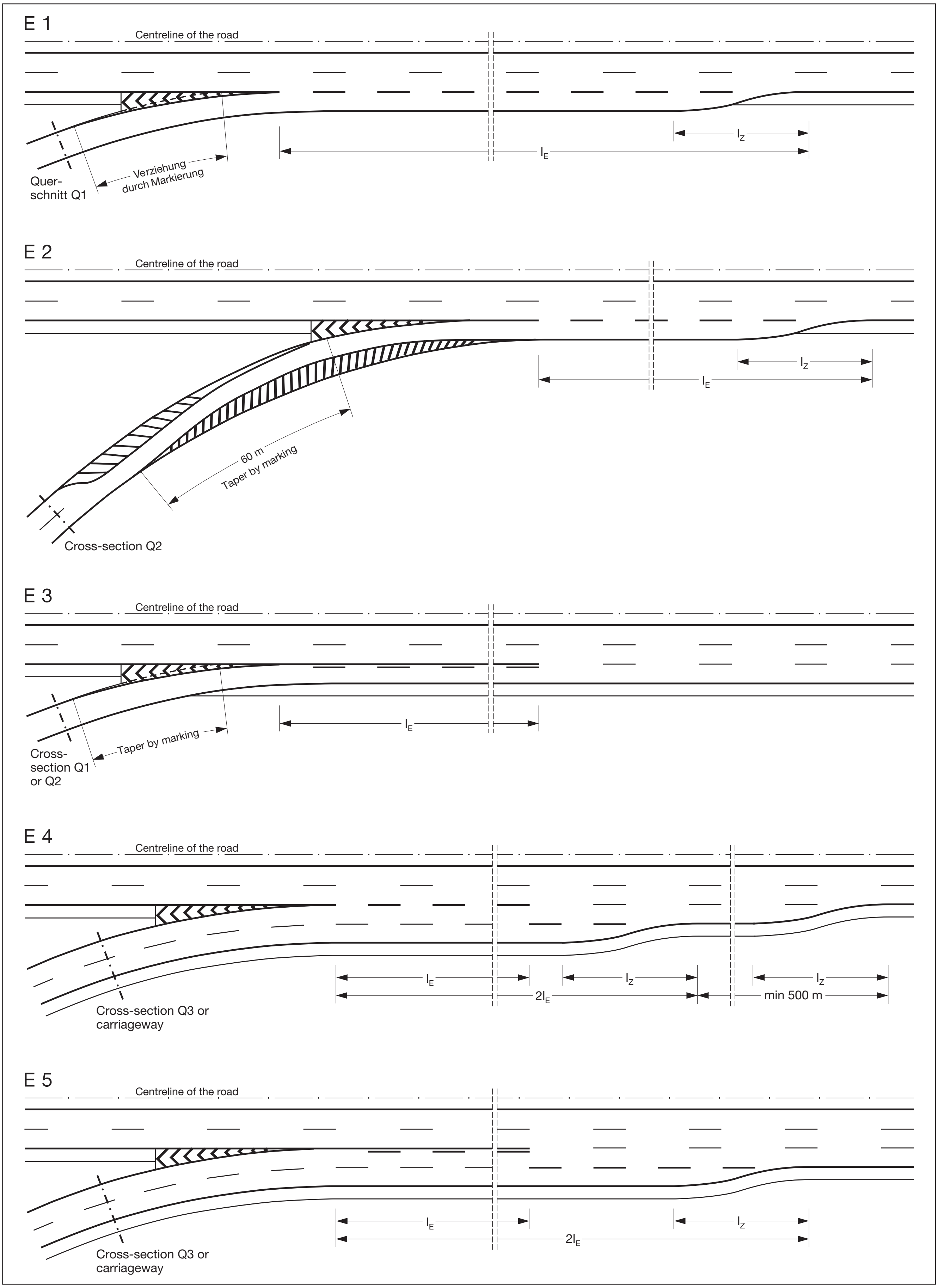


Fig. 59: Types of entries on mainline carriageways

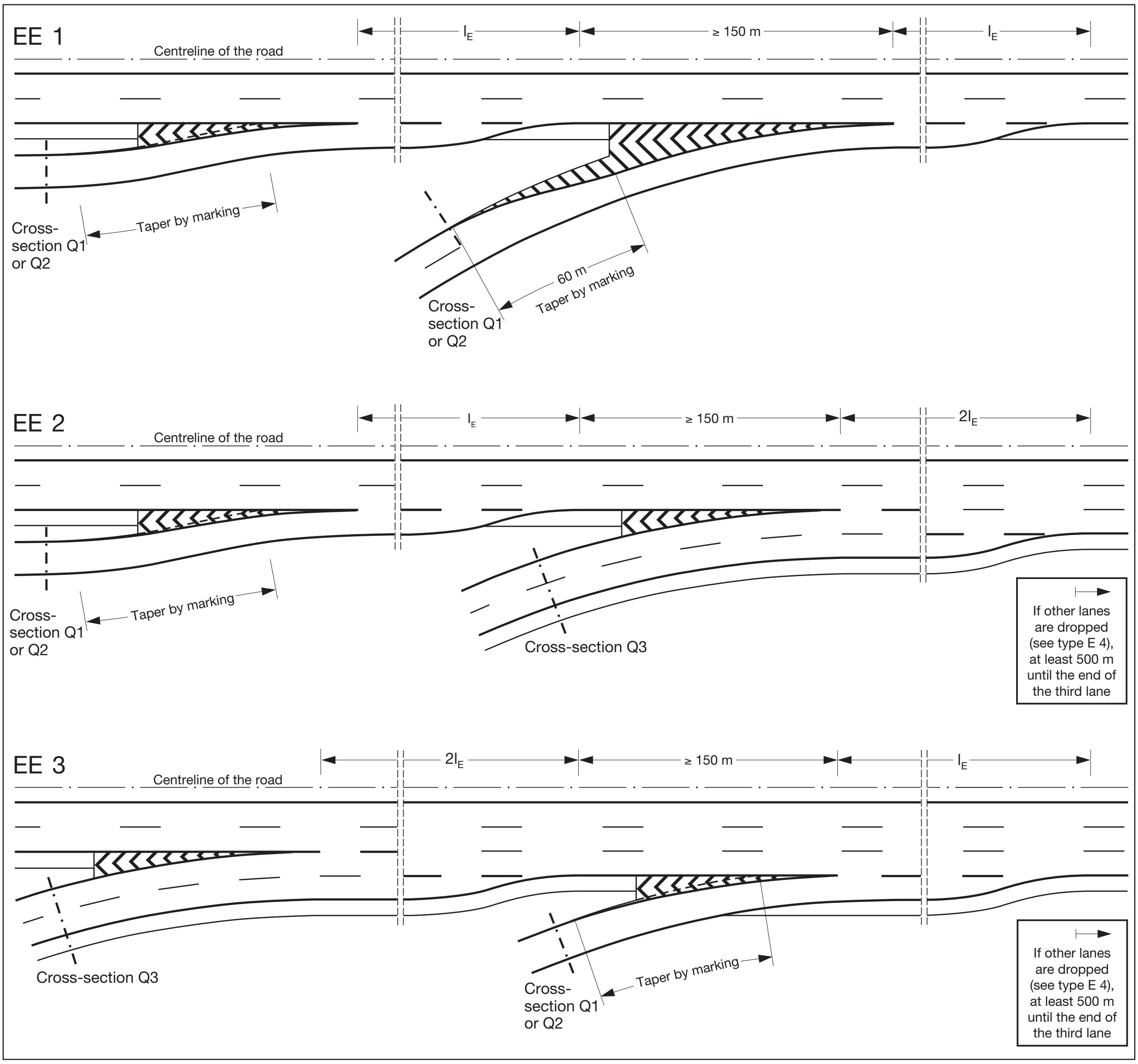


Fig. 60: Types of consecutive entries on mainline carriageways

time. Moreover, a painted island should also be provided in the left-hand lane ahead of the painted island in the right-hand lane. This ensures that the vehicles in the left-hand lane move into the right-hand lane with the slower-moving traffic (or 'truck lane').

Entry type E 3 shall be used in those situations where cross-section Q 1 or Q 2 suffices on the entry slip road, but where the merging traffic flow is so heavy that it cannot be accommodated by the mainline carriageway using entry types E 1 or E 2.

Entry type E 4 or **entry type E 5** shall be used in situations where a two-lane connector road cross-section (Q 3) is necessary in order to accommodate traffic loads. In this entry type, a lane is gained on the left-hand side of the slip road lane; the right-hand lane ends in a merging lane (entry type E 5). If the traffic load is such that the mainline carriageway does not require three lanes (if, for example, the merging traffic is heavier than the through traffic either temporarily or permanently), the added lane can be dropped again no sooner than 500 m after the end of the merging lane (entry type E 4). The lane drop should be made clear to the driver by the use of traffic guidance signs that provide distance information.

Entry type EE 1 shall be used in those situations where cross-section Q 1 or Q 2 suffices for both entry slip roads.

Entry types EE 2 and **EE 3** shall be used in situations where one of the two entry slip roads has to have cross-section Q 3 for traffic load reasons.

In addition, **entry types E 1***, **E 3***, and **E 4*** can be used on EKA 3 motorways. Entries from the left are only permissible in the form of a lane gain. Entry type E 4*,

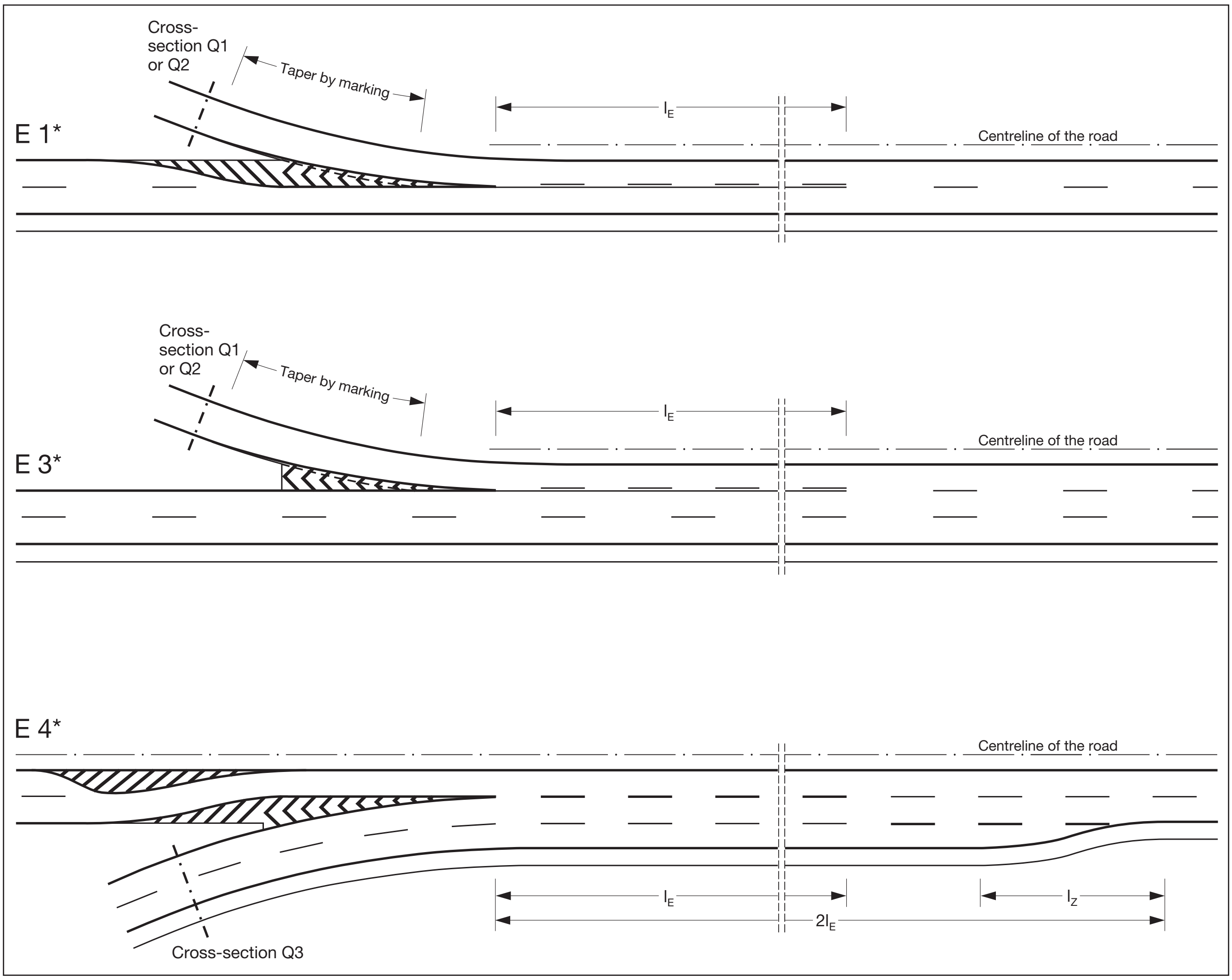


Fig. 61: Additional types of entries on mainline carriageways on EKA 3 motorways

which features the lane drop on the main carriageway upstream of the entry, is used instead of entry type E 4 on EKA 3 motorways because the conditions for applying entry type E 4 do not generally exist on these motorways.

Entry type ER 1 shall be used in situations where the slip road can be continued as a single lane after the entry. In the area where the two lanes run parallel to each other (merging area), cross-section Q 2 can be used as an alternative to the use of two connector road cross-sections Q 1. In this case, the lanes and the edge of the carriageway must be tapered in such a way as to create a visually pleasing solution.

Entry type ER 2, which features the addition of two slip roads with cross-sections Q 1 or Q 2, can be used in those situations where the cross-sections Q 1 or Q 2 are sufficient upstream of the merging point, but where the cross-sections Q 2 or Q 3 are necessary downstream of the merging point.

Entry type ER 3 is expedient in those situations where a two-lane connector road (cross-section Q 2 or Q 3) has to merge with a connector road with the cross-section Q 1 or Q 2 and the merging traffic flow is lighter than the through traffic flow.

Entry type ER 4 can be used in those situations where the traffic volume in the right-hand merging slip road is higher than that on the through carriageway. Alternatively, the connector road with the lower traffic volume can be merged at the merging point or merged with the mainline carriageway using a separate entry (entry type EE 2).

If the entry into the connector road system is followed by an entry onto the mainline carriageway, a minimum spacing of 50 m must be maintained between the two entries.

Evidence of sufficient entry sight distance in accordance with Fig. 63 must be provided for all entries. The fields of vision that must be kept free shall be indicated in the plan documents.

For all entry types with two-lane entry slip roads, the use of lane signalling with the traffic-dependent, alternating feeding of traffic onto a lane on the mainline carriageway and on a lane on the entry slip road shall be

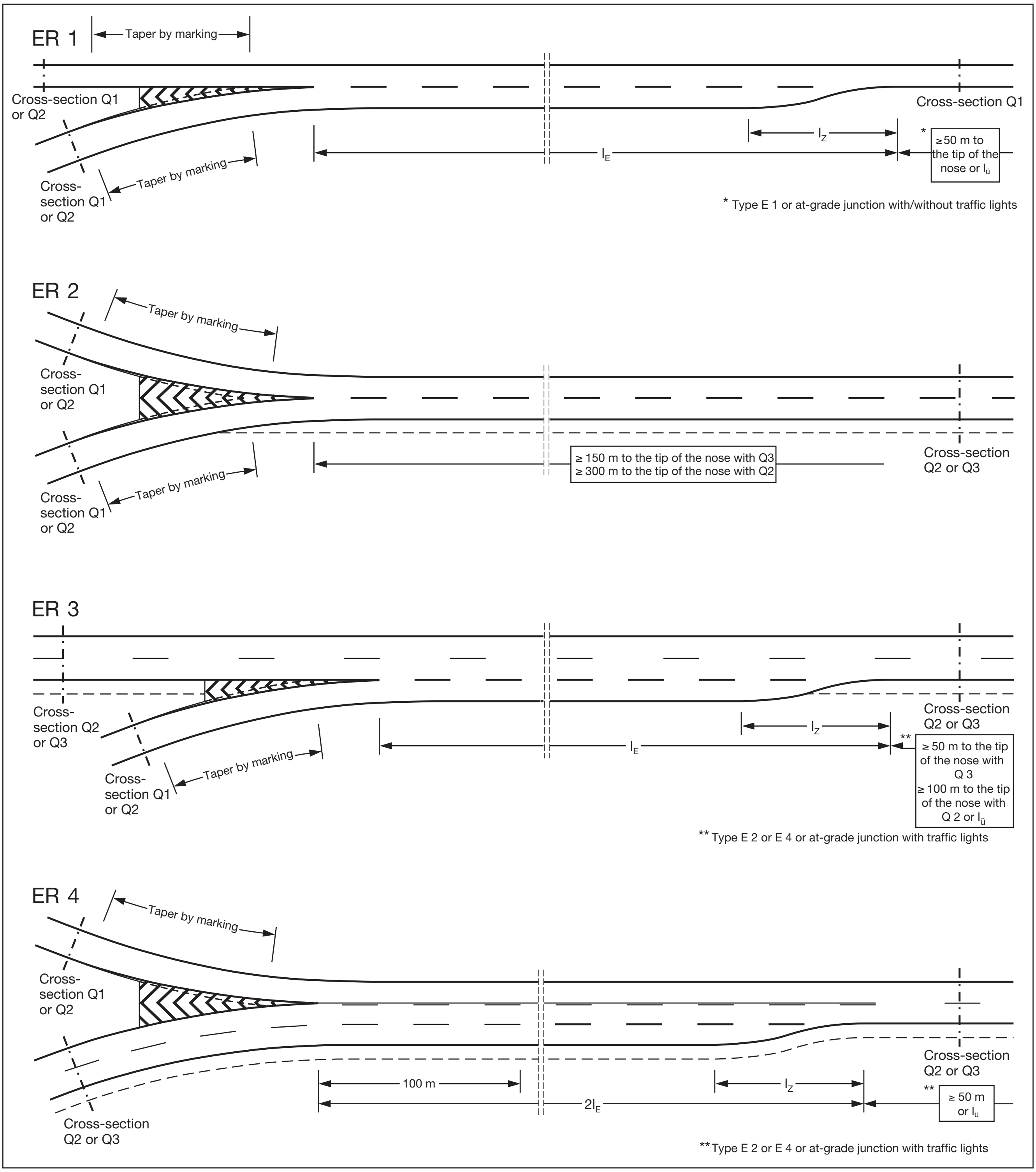


Fig. 62: Types of entries in the connector road system

investigated (Section 7.10). Lane signalling can also facilitate the merging of the two merging traffic flows at double entries (EE types).

Regardless of the entry type situations outlined here, the quality of the traffic flow for the entry should be checked in accordance with the HBS.

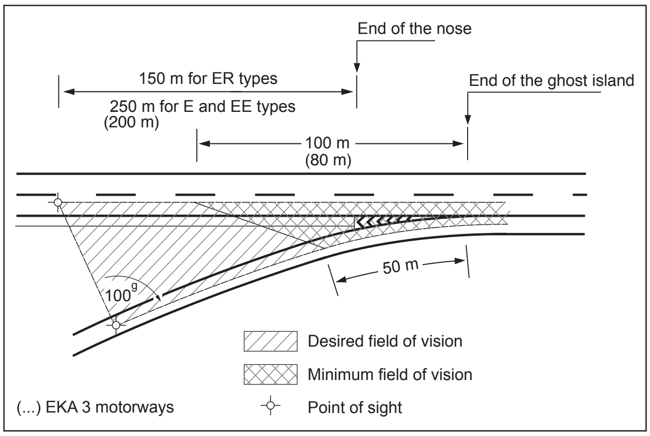


Fig. 63: Entry sight distance

6.4.5 Weaving areas

6.4.5.1 Traffic engineering significance

Weaving occurs in those situations where an entry follows so closely after an exit on a multi-lane carriageway (mainline carriageway or connector road) that the traffic flow cannot flow without disturbance on the intervening section. A weaving area comprises an initial lane gain, the actual weaving section, and a subsequent lane drop. If the number of lanes gained and dropped is balanced (which then corresponds to the number of weaving lanes), the weaving area is said to be symmetrical.

There are four traffic flows in a weaving area: the inner non-weaving flow (through traffic on the carriageway), the outer non-weaving flow (merging traffic that leaves the motorway at the next exit), and the two weaving flows that cross each others' paths (diverging traffic that has arrived on the carriageway; merging traffic that intend to continue on downstream on the carriageway). The main characteristic of a symmetrical weaving area is that a vehicle in the weaving flow has to complete at least one lane change.

In accordance with the traffic flow pattern, there are four different kinds of motorway weaving areas:

a) weaving areas on cloverleaf link roads (no inner or outer non-weaving lanes),

b) cloverleaf weaving areas with weaving lanes on the mainline carriageway (no outer non-weaving lane),

c) weaving area on a link road between two junctions (no inner non-weaving lane),

d) all other weaving areas, e.g. between two junctions on a mainline carriageway, on a long link road between more than two junctions, or in the connector road system of a complex junction (non-weaving lanes provided).

The number and size of the traffic flows involved determine the level of difficulty of the weaving manoeuvre and the structural layout of the weaving section. The lane configuration should be designed to accommodate the traffic flows identified in the traffic flow pattern. By providing a link road instead of a weaving lane on the mainline carriageway, the through traffic flow on the mainline carriageway remains unaffected by the weaving, and weaving manoeuvres are simplified by the fact that there is no inner non-weaving flow.

In traffic engineering terms, a long weaving lane between two junctions only makes sense in those situations where the outer non-weaving flow is so heavy that the provision of a long weaving lane would provide noticeable relief for traffic on the through lane in the weaving section. Otherwise, it is less expensive to return to the standard cross-section of the non-weaving section. On the other hand, in those situations where the outer non-weaving flow is very heavy – especially in short weaving areas – the provision of a second weaving lane can significantly improve the level of service because it means that the non-weaving flow has its own lane and no longer comes in contact with the weaving area.

The traffic forecast frequently does not provide an unequivocal traffic flow pattern for a peak hour, but several very different flow patterns have to be accommodated by a single engineering solution. For this reason, the traffic flow for every individual design variant shall be checked to make sure that it provides the required quality of service. If necessary, simulations should be used for this purpose.

6.4.5.2 General layout of weaving areas

The parameters for the structural layout of a weaving area are:

– the lane configuration (number of lanes in the four interfaces and in the weaving section, symmetrical or asymmetrical layout) and
– the weaving length (distance from the end of the nose at the entry to the end of the nose at the exit).

The marginal conditions for the lane configuration are largely specified by the cross-sections of the upstream and downstream mainline carriageways or connector roads. The number of lanes in the weaving section itself can be influenced by the number of additional weaving lanes that can be provided. To a more limited degree, the weaving length can also be influenced.

The following design remarks must be observed:

– Excessively long weaving sections do not make a significant change to the weaving behaviour or the utilization of the length. For this reason, they are not necessary in traffic engineering terms. However, situations can occur where junctions are very closely spaced as a result of the extension of a merging lane to the point where the next diverging lane begins. In practice, weaving lanes of up to 1,500 m have been built.
– Within the weaving sections, the weaving lanes must be delineated from the through lanes by broken edge marking ('broad line marking'). The regulations in the RMS also apply.
– The width of the weaving lane corresponds to the width of the adjacent through lane. A hardstrip 0.50 m wide is also provided on the outer edge of the weaving area.

Hard shoulders should only be provided on short weaving sections in those situations where cross-section Q 3 or the cross-section of a mainline carriageway occurs on a connected connector road. Otherwise it is sufficient for all protective devices alongside the weaving lane to be moved back far enough to allow vehicles to stop on the verge in an emergency (the width of the verge – which must be designed to be stable – to the protective device should be 2.00 m). A hard shoulder should always be provided on longer weaving sections on mainline carriageways on EKA 1 motorways (e.g. between two junctions).

6.4.5.3 Weaving area types and the situations in which they are used

Only standard symmetrical weaving area types are described in this section. In those situations where the weaving flows differ considerably, asymmetrical weaving areas are expedient if the asymmetrical traffic flow pattern remains stable over the course of the day and week. The following weaving area types can be used for all design classes.

Fig. 64 shows the **universally applicable weaving area type (V type)**. This type can be used both on the mainline carriageway and in the connector road system. The V types can also be used appropriately on three- or four-lane mainline carriageways.

Fig. 65 shows the special **weaving areas for the connector road system (VR types).** In principle, they correspond to the V types, but are not suitable for use on the mainline carriageway because they only have **one** through lane.

The application parameters for a weaving area are based on the weaving traffic flow and the traffic flows across the cross-section on the mainline carriageway

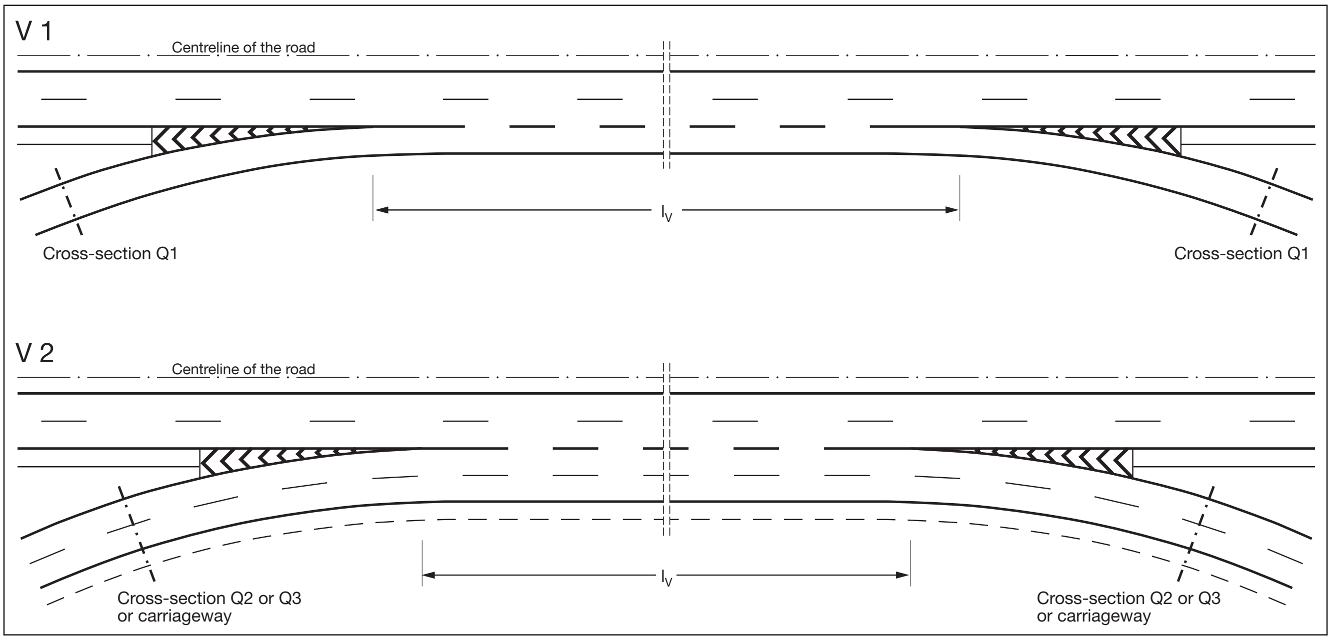


Fig. 64: Types of universally applicable weaving areas

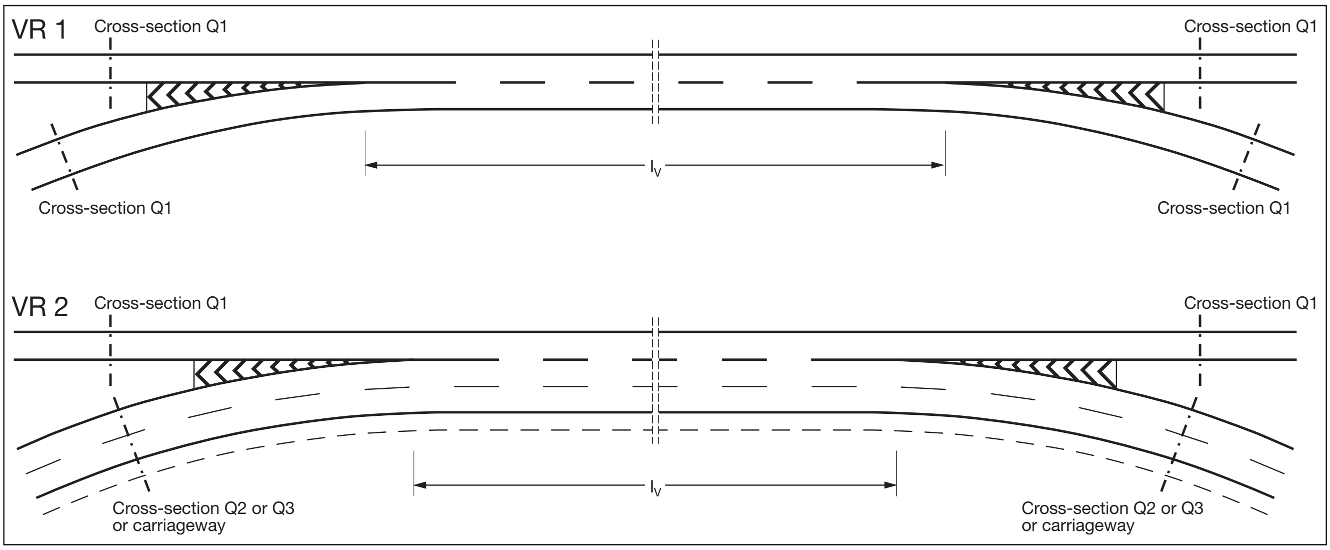
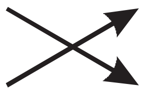
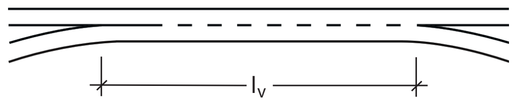
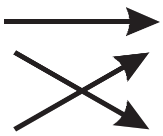
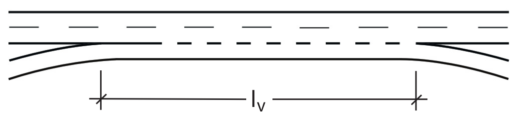
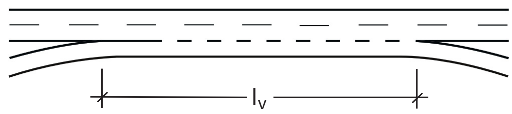
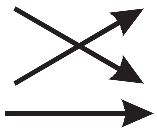
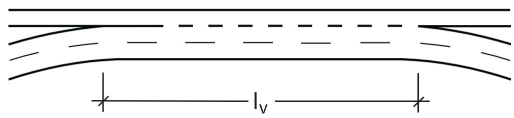
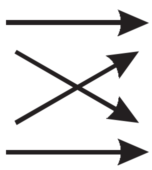
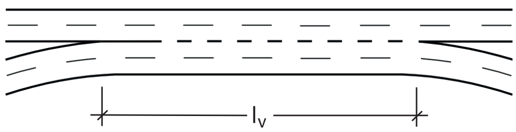


Fig. 65: Special types of weaving area for the connector road system

or on the slip road after the weaving area. Table 25 lists the situations in which the individual weaving area types are used in relation to the qualitative traffic flow patterns for the weaving section and the recommended weaving lengths.
The fact that there are a number of different types means that the weaving area can be selected using the traffic flow patterns of the weaving area in accordance with Table 25. Accurate evidence must be provided in accordance with the HBS or, if necessary, by simulation. As a result, it may be necessary to apply a speed limit that corresponds to the weaving speed stipulated by the HBS in consultation with the traffic authority.

Table 25: Application parameters and minimum weaving lengths l_V for weaving area types

Traffic flow pattern (in accordance with Section 6.4.5.1)	**Location of the weaving area**	
	On the mainline carriageway	**In the connector road system**
Situation a)  ‘no inner or outer non-weaving flows’		**VR 1**  • Cloverleaf link road l_V = 200 m l_V = 180 m (where permissible speed (V_{zul}) = 80 km/h)*
Situation b)  ‘no outer non-weaving flow’	**V 1**  • Cloverleaf **Not permissible for EKA 1 A** l_V = 250 m l_V = 200 m (where permissible speed (V_{zul}) = 100 km/h)* l_V = 180 m (where permissible speed (V_{zul}) = 80 km/h)*	**V 1**  • Link road over ≥ 3 junctions with very low outer non-weaving flow l_V = 250 m l_V = 200 m (where the permissible speed (V_{zul}) = 100 km/h)*
Situation c)  ‘No inner non-weaving flow’		**V 2** l_V as in situation d) • Link road between 2 junctions **VR 2** l_V as in situation b)  • Slip road at complex junctions with very low inner non-weaving flow
Situation d)  ‘Non-weaving lanes provided’	**V 2**  • Between 2 junctions **Not permissible for EKA 1 A** l_V = 300 m l_V = 250 m (where permissible speed (V_{zul}) = 100 km/h)* l_V = 200 m (where permissible speed (V_{zul}) = 80 km/h)* Special situation for EKA 3: l_V =180 m (where permissible speed (V_{zul}) = 60 km/h)*	**V 2** • Long link road over ≥ 3 junctions or • Slip road at complex junctions l_V = 300 m l_V = 250 m (where permissible speed (V_{zul}) = 100 km/h)* l_V = 200 m (where permissible speed (V_{zul}) = 80 km/h)*

* Possible in exceptional cases where the given permissible speed (V_{zul}) is applied in consultation with the traffic authority on the mainline carriageway or in the connector road system.

7 Equipment

7.1 General remarks

Harmony and unity between design, equipment, and operation is essential to ensure the safe and smooth flow of traffic.

For this reason, the RAA contain not only technical specifications relating to design, but also fundamental information regarding the elements of motorway equipment.

The criteria for the use of these elements as well as their design and layout are regulated in dedicated guidelines and regulations. In such cases, the RAA describe how the relevant equipment elements are integrated into the planning and design process and make reference to the relevant regulations.

7.2 Carriageway markings and signing

The main requirement for **carriageway markings** is that they be highly visible during the day, during the night, and in wet conditions. In view of the fact that other sources of information provide drivers with visual guidance during daylight hours, priority is given to night-time visibility.

The use and application of markings is regulated by the Guidelines on Road Markings *(Richtlinien für Markierungen von Straßen*, RMS*)*. Minimum values for the retro-reflectivity of markings and their visibility at night are specified by the Additional Technical Terms of Contract and Guidelines on Road Markings *(Zusätzliche Technischen Vertragsbedingungen und Richtlinien für Markierungen auf Straßen*, ZTV M*).*

Permanent markings are white; temporary markings (e.g. marking used around construction works) are yellow. In accordance with the German Road Traffic Regulations (StVO), yellow markings take precedence over white markings and should be used if both markings are warranted. For this reason, yellow markings must be at least as recognisable as white markings.

Markings should be clearly recognisable at a distance of between 75 and 100 m. To make sure that this is the case, (minimum) technical levels are specified for night-time visibility in dry and wet conditions. Additional visual guidance is provided by reflectors on marker posts (post-mounted delineators) or signs indicating curves. Road studs may also be used around construction works.

Only type II carriageway markings shall be used on motorways. Because their retro-reflecting parts project above the level of the carriageway marking, they are more visible at night in wet conditions.

Signs are positioned in accordance with the German Road Traffic Regulations (StVO) and the relevant General Administrative Provision (VwV-StVO).

The road traffic authorities are responsible for the approval and positioning of signs. The authority responsible for the construction of the motorway is responsible for erecting them. To ensure signing that is compatible with the motorway and is reduced to the minimum necessary, traffic sign plans must be drawn up at an early stage and agreed with the road traffic authority and the authority responsible for constructing the road.

In accordance with Section 45(9) of the StVO, traffic signs and traffic control devices shall only be erected in places where the specific conditions make it necessary to do so. Above all, restrictions and prohibitions may only be imposed on free-flowing traffic if specific local conditions pose a threat well in excess of the general risk. Examples of such situations include:

- situations where different traffic streams are combined and then separated on a motorway at short intervals;
- situations where there is a quick succession of entries and exits with a large number of directive signs;
- situations where design elements with near limiting values are used or even overlap on motorways that otherwise allow for fast driving;
- situations where local accident patterns make it necessary.

Of all traffic signs on motorways, directional signs are particularly important. Regulations stipulated by traffic laws and above all the Guidelines for Directional Signing on Motorways (RWBA) and the Guidelines for Directional Signing on Highways other than Motorways (*Richtlinien fur die wegweisende Beschilderung außerhalb von Autobahnen*, RWB) must be observed.

The following guidance requirements must be met:

- Signs should contain as few destinations as possible to ensure that the information on destinations is easy to recognize and understand.
- Information on destinations should provide continuous guidance along a route and guidance to destinations should be structured in a logical manner.

A maximum of four exit destinations should be included on motorway direction signs and advance direction signs.

When deciding on the solution for a concrete/specific situation, the merits of providing individual drivers with the most detailed information possible and the system-related restriction to the smallest possible amount of information should be weighed up. Information must be restricted because of the fact that only a limited amount of information can be absorbed and processed to assist driving decisions when travelling at speed. Moreover, there is the risk that excessive signing could confuse the road user or distract the driver. It could also lead to a decrease in acceptance and compliance with traffic regulations, thereby hampering road safety.

The erection of private information signs or the inclusion of private destination information on directional signing is regulated by the Guidelines on Advertising on (Federal) Motorways from the Perspective of Road Traffic Laws and Road Laws (BMV ARS 32/2001).

7.3 Traffic guidance equipment

The Code of Practice for the Positioning and Design of Vertical Traffic Guidance Equipment *(Hinweise für die Anordnung und Ausführung von senkrechten Leiteinrichtungen*, HLB) applies to the erection of traffic guidance equipment.

Marker posts (Z 620 StVO) are used for this purpose. Marker (or delineator) posts on the mainline carriageway are generally spaced 50 m apart.

7.4 Vehicle restraint systems (roadside safety barriers)

The Guidelines for Passive Protective Devices on Roads using Vehicle Restraint Systems *(Richtlinien für passiven Schutz an Straßen durch Fahrzeug-Rückhaltesysteme*, RPS*)* in conjunction with the standard DIN EN 1317 apply to the use of vehicle restraint systems.

- The purpose of vehicle restraint systems is to minimize the consequences of accidents as much as possible. They are used in the following situations:
- to protect uninvolved persons, areas alongside the road that require special protection, or oncoming traffic;
- to protect the occupants of errant vehicles from the serious consequences of leaving the carriageway, e.g. from plummeting down an incline or colliding with dangerous obstacles alongside the carriageway.

Before vehicle restraint systems are installed, an investigation shall be carried out to determine whether high-risk points can be avoided, eliminated or structurally redesigned.

Significant performance characteristics of protective devices include:

- level of containment,
- effectiveness range class,
- collision severity level.

Protective devices are intended to contain and deflect vehicles of different size and weight (level of containment) and, in so doing, to ensure a certain degree of lateral displacement (effectiveness range class or working width class). At the same time, the effect on the occupants of the errant vehicle (collision severity) should be as low as possible.

The marginal planning conditions influence the choice of restraint system. In this regard, the effectiveness range class, the choice of restraint system and the amount of space available in the central reserve are closely related. The fact that central reserves on EKA 1 and EKA 2 motorways are 4.0 m wide means that a particular product need not be specified when tendering vehicle restraint systems on these motorways.

Vehicle restraint systems generate costs or entail additional work for the authority responsible for construction of the road. These costs/this work includes:

- investment costs,
- repair costs,
- maintenance costs,
- upkeep of green areas, and
- cleaning and winter maintenance costs.

The costs to the road user include accident costs in the case of a collision with a restraint system or time costs during the repair of restraint systems as a result of the possible obstruction of traffic.

In terms of collisions involving passenger cars, there are two types of vehicle restraint system: rigid systems (e.g. concrete protection walls) and deformable systems (e.g. steel safety barrier). Rigid systems have a number of general advantages: deformation is limited when a heavy vehicle collides with them, which means that limited space is needed for displacement (or deflection) in the event of collision, and they generally require less repair. The disadvantage of such systems is the greater impact on the occupants of vehicles that collide with them and the higher cost of repairs if the barriers are severely damaged.

In view of the fact that they require fewer repairs and consequently avoid congestion costs in the event of repairs, rigid systems are generally more economical to use on busy motorways, especially when used in the central reserve.

In cases where a variety of different protective device designs are permitted by the RPS, the following aspects should be taken into consideration when selecting a system:

- investment costs,
- the ability to provide stopping sight distance, depending on the height of the restraint system ($h \leq 0.90$ m), and
- ease of repair in the event of a collision.

In the vicinity of construction works, transportable elements are used to separate traffic flowing in different directions in order to improve safety during temporary lane operations with two-way traffic on a single carriageway.

7.5 Emission and pollution control structures

7.5.1 General remarks

The aspects of emission and pollution control should be taken into consideration at an early stage of the motorway planning process. Emission and pollution control structures are often necessary, in particular in close proximity to housing areas, in order to provide protection against noise and air pollution.

The following control measures can be considered:

- the alignment of the road in the cut,
- emission control embankments, steep embankments, and barriers,
- noise-reducing pavements,
- partial and full coverage,
- Troughs, tunnels, or enclosure.

7.5.2 Noise control

The Federal Pollution and Noise Control Act (*Bundes-Immissionsschutzgesetz,* BImSchG) in conjunction with the Road Traffic Noise Control Regulation (*Verkehrslärmschutzverordnung*, 16th BImSchV) make sure that there are no adverse effects on the environment as a result of road noise when constructing new roads or making major changes to existing roads (noise prevention). The authority responsible for the construction of an existing motorway can also implement voluntary noise control measures (noise abatement).

These measures can be either active (on the road itself) or passive (on buildings in need of protection) in nature.

The Guidelines for Noise Control on Roads (*Richtlinien für den Lärmschutz an Straßen*, RLS) and the Guidelines for Road Traffic Noise Control on Federal Trunk Roads Constructed by the Federal Government (*Richtlinien für den Verkehrslärmschutz an Bundesfernstraßen in der Baulast des Bundes*, VLärm - SchR) contain calculation procedures and notes on when noise control measures are necessary and the appropriate dimensions for the barriers.

7.5.3 Air quality management

As part of the preliminary planning and design planning stages, the impact of air pollutants generated by road construction projects on both people and nature or ecosystems shall be investigated; if necessary, action shall be taken.

The impact is estimated on the basis of the Information Sheet concerning Air Pollution on Roads with or without Peripheral Development *(Merkblatt über die Luftverunreinigung an Straßen ohne oder mit lockerer Randbebauung,* MLuS 2005*)* in its amended version. If these estimates are not applicable in certain special cases, additional air pollution assessments must be undertaken. In this regard, the stipulations of the 22nd Regulation on the Implementation of the Federal Pollution and Control Act (*22. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes*, 22nd BImSchV) must be observed.

There are only a limited number of structural measures that can be taken to reduce air pollution levels on motorways. Emission control barriers or planting vegetation along the roadside only have a limited mitigation effect on air pollution. Enclosures should be avoided where possible because of the high investment and operation costs involved.

7.5.4 Measures

The dimensions of any necessary protective devices shall be determined on the basis of the results of technical noise or air pollution assessments. When implementing structural measures, one should not deviate from these dimensions; otherwise it will not be possible to ensure the calculated emission control values for those affected by the pollution.

The lateral emission control structures are positioned in the cross-section of the road in accordance with the Standard Drawings for Noise Screens That Are Not Part of Civil Engineering Structures (*Richtzeichnungen für Lärmschirme außerhalb von Kunstbauten*, RiZAK), the Additional Technical Terms of Contract and Guidelines for the Implementation of Noise Barriers on Roads (*Zusätzlichen Technischen Vertragsbedingungen und Richtlinien für die Ausführung von Lärmschutzwänden an Straßen*, ZTV-Lsw), and the corresponding RiZ-ING.

The standard distance between a barrier and the edge of the paved carriageway is 2.50 m. Aspects of road safety, e.g. those relating to a reduction in visibility or problems of glare (e.g. transparent barriers in curves), should be taken into consideration at the planning stage.

The design of noise screens should be in line with the Recommendations for the Design of Noise Control Facilities on Roads *(Empfehlungen für die Gestaltung von Lärmschutzanlagen an Straßen).*

7.6 Anti-glare systems

Anti-glare systems are used to protect road users from being dazzled by the head lights of oncoming vehicles or other light sources. They are positioned not only between the carriageways, but also between motorways and other roads or railway lines that run close beside the motorway.

Anti-glare systems can be expedient in:

- areas with high accident rates in the dark,
- areas with high traffic loads at night,
- areas with unfavourable topographical conditions that lead to severe dazzling (e.g. on crests, in sags and curves, in areas where the opposite carriageways are at different levels),
- areas with long straights and areas around civil engineering structures and motorway service areas,

– areas around grade-separated intersections where loops and tangential carriageways run close by each other.

Anti-glare protection shall generally only be provided for passenger cars. For this reason, anti-glare systems that are much less than 1.00 m in height are sufficient for a constant longitudinal slope. In this respect, vehicle restraint systems in the central reserve with a height of h ≥ 0.85 m suffice without the need for technical anti-glare attachments. If the motorway gradient is unfavourable, additional anti-glare screens may be necessary.

In those cases where carriageways are at different levels, and where the crossfalls of the carriageways are very similar, a higher anti-glare system may be necessary in order to screen vehicles on the lower carriageway from light beams from vehicles on the higher carriageway. If the crossfalls and longitudinal gradients of the two carriageways are very different, the need for anti-glare systems should be assessed on a case-by-case basis. Depending on the cross-section and the differences in height, glare can be prevented without recourse to anti-glare screens using an appropriate geometrical layout for the road.

For information on the use of plants for anti-glare protection, please refer to section 7.7.

Anti-glare systems must not restrict the necessary stopping sight distance in any way.

Anti-glare screens are mounted on vehicle restraint systems, must be compatible with them, and must not impair the effectiveness of the vehicle restraint systems in any way.

Brief gaps in long stretches of anti-glare screen should be avoided.

Anti-glare systems must be effective to their full height. A maximum gap of 0.02 m between the vehicle restraint system and the lower edge of the anti-glare screen is permissible.

The structural design of anti-glare systems shall be regulated in accordance with the standard Anti-glare Screens for Roads (*Blendschutzzäune für Straßen*, DIN EN 12676).

7.7 Planting and landscaping

The Federal Nature Conservation Act in conjunction with relevant *Land* regulations stipulates the conservation of nature and the landscape, which covers among other things the performance and functional capability of the natural balance and the overall appearance of the landscape. It includes the obligation to restore the appearance of the landscape in an appropriate manner or to create a new landscape appearance after any encroachment into the landscape. In the case of road construction-related encroachment into the landscape, this obligation can generally be met by designing and planting the roadside area in a manner that suits the character of the landscape.

Planting the roadside area is not only important in terms of landscaping and aesthetics, it also fulfils important functions relating to the protection of engineering structures. Such functions include:

– integration of the road into the landscape,

– protection of the engineering structure (erosion protection),

– screen function and anti-glare protection,

– emission control.

Road safety considerations should always be taken into account when planting roadside areas along motorways. For example, when considering what the vegetation will look like when fully grown, it is important to make sure that necessary sight distances will not be restricted at any stage of the vegetation's growth. This is particularly important as regards the central reserve on motorways and sight triangles at junctions. Vegetation should not be planted in those cases where the vegetation would restrict the necessary stopping sight distance or the visibility of traffic signs.

Planting the central reserve generates considerable work in terms of road operation and upkeep, necessitating the closure of the left-hand lane, which disrupts the flow of traffic. The ecological function of vegetation is lower in the central reserve and is therefore mainly used to improve the appearance of the road as a transport structure, to protect against side winds, and to provide anti-glare protection. Consequently, the central reserve should, as a rule, only be planted on less busy motorways. In these cases, low-growing species of plants that require pruning or any other kind of upkeep as infrequently as possible, should be used.

The landscape management plan must ensure that road equipment is visible at all times. The locations in the signing plan and fields of vision must be kept free of vegetation.

Verges (Section 4.2.3.7) must be stable in design. Planted verges improve pollution retention in the soil of verges. Low grasses or gravel should preferably be used.

Supplementary information on the integration and design of roadside areas is contained in RAS-LP 1 and RAS-LP 2 as well as in the Recommendations Regarding the Integration of Roads into the Landscape *(Empfehlungen für die Einbindung von Straßen in die Landschaft*, ESLa).

The necessary upkeep of undergrowth and shrubs is outlined in the Information Sheet concerning Road Operation Services: Upkeep of Green Areas (*Merkblatt für den Straßenbetriebsdienst, Teil: Grünpflege*).

Trees should not be planted near the carriageway on motorways.

7.8 Game fences

Game fences are erected in order to keep game off the roads. They are used to protect both drivers and animals, thereby helping to improve road safety.

Game fences are erected in accordance with the Guidelines for Game Fences along Federal Trunk Road Network (*Richtlinien für Wildschutzzäune an Bundesfernstraßen*). They contain criteria for the positioning of game fences and information on their structural design.

The obligation to protect traffic is adequately met by the erection of hazard warning sign 142 (Game crossing) from the German Road Traffic Regulations (StVO). As a rule, however, supplementary measures are taken, e.g. the application of speed limits or the removal of vegetation to improve visibility. Game fences are, therefore, a voluntary measure taken by the authority responsible for the construction of the motorway. Nevertheless, for reasons of safety they are standard on motorways in those areas where there is reliable evidence that there is game in the area and/or the criteria for constructing game fences (e.g. number of accidents) are met. From an ecological point of view, they also serve the purpose of guiding game to animal crossings.

The road construction authority is responsible for building and maintaining the game fences. It is up to either the forestry administrations or the owners of private preserves to check the fences for damage. Appropriate agreements must be concluded.

7.9 Telecommunications equipment

Telecommunication equipment is of great importance for the road operation service, traffic engineering, and tunnel operation.

The federal motorway telecommunications network (BAB-Fm-Netz) comprises the following elements:

- cable networks,
- active transmission and switching technology,
- private mobile radio, emergency telephone, and fault alarm systems including roadside emergency telephones,
- antenna masts and antennae, and
- other electrical equipment such as power supply systems and emergency power supply systems.

Other components of the federal motorway telecommunications network include:

- telecommunications depots,
- technical operation rooms in motorway maintenance depots,
- cable boxes,
- switching boxes,
- cable branch cabinets,
- cable vaults,
- cable terminal equipment,
- grounding and equi-potential bonding systems.

The telecommunications and signalling services can be allocated to the following areas:

- voice services (emergency telephone calls via an emergency call network with roadside emergency telephones),
- telephone network (AUSA) in authorities and premises for the management of the federal motorway network that are owned by the road construction authority,
- private mobile radio for steering and managing the road operation service,
- data transfer services and applications (data networks for tele-control and tele-monitoring systems in technical operating facilities on the federal motorway network, including tunnels),
- data networks for the road condition and weather information system (SWIS),
- data networks for traffic engineering applications such as traffic management, axle load registration, and traffic data registration,
- operation networks for tunnels, bridges, pump stations etc.

The space and access routes required for the telecommunications equipment must be included in the plan documents.

The telecommunications cable shall be included in the standard cross-section diagram for the preliminary design. Depending on the alignment of the route, it is on one side of the motorway, either to the north or to the east.

The cable trenches for the telecommunications cable for the section of the road shall be included outside the rounding area of an embankment. As a rule, cable trenches are 0.30 m wide and 1.0 m deep.

The distance between the border of the land acquisition and the axis of the cable trench shall be 1.0 m.

Any necessary game fences shall be on the land acquisition border side of the cable trench.

As a rule, roadside emergency telephones are spaced 2 km apart on motorways. They shall be positioned in such a way that both they and the people that use them are protected against vehicle collision. In cases where emergency telephones are positioned behind continuous vehicle restraint systems, openings must be created to allow disabled people, especially wheelchair users, to reach the emergency telephone. Small black arrows on the marker posts indicate the location of the nearest emergency telephone.

As a rule, the planning of telecommunications equipment and ancillary facilities is a specialist activity. Nevertheless, the acceptance of the telecommunications engineering systems must be agreed with those responsible for operations.

7.10 Traffic control systems

Traffic control systems make an important contribution to increasing road safety and improving the quality of the traffic flow on motorways.

They use variable message signs to adapt the traffic flow to suit prevailing conditions. A number of different kinds of traffic control system exist for a variety of applications:

- **section-specific traffic control systems** for the harmonization of traffic flow by means of congestion-related speed limits and hazard warnings,
- **network traffic control systems** for the diversion of traffic streams onto alternative routes,
- **junction traffic control systems** for the control of merging traffic at entries or in weaving sections as well as lane signalling at exits,
- **hard shoulder running** at peak times (Section 8.8).

Traffic control systems are mainly considered for stretches of motorway with high traffic volumes with a high risk of congestion or at junctions with a conspicuously high accident rate.

Experience shows that the use of traffic control systems

- harmonizes the traffic flow and reduces congestion. In areas characterized by high traffic volumes, they help to keep the traffic flow stable for longer.
- can significantly reduce the risk of accidents. Above-average accident rates can be reduced to approximately the average accident rate for federal motorways.

The installation of a traffic data collection system should be investigated for every motorway section in order to gather information about traffic flow and traffic volume. The data thus collected could be used for a variety of purposes, e.g. as a decision-making tool for any necessary traffic control systems or other structural or traffic-related measures. It would also be a valuable source of traffic information.

One particular advantage of variable speed limits over static signs is that they can be adapted to suit prevailing traffic and weather conditions.

Drivers generally heed information on variable message and variable speed limit signs. One aspect that is very important for the acceptance of the systems is that the entity operating the system (road construction authority, traffic authorities, police) displays an appropriate speed limit.

The use of traffic control systems is subject to the Guidelines for Traffic Control Systems *(Integrierte Regelwerke für Verkehrsbeeinflussungsanlagen*, RVBA).

As a rule, the planning of traffic control systems is a specialist activity.

8 Special technical design and operation considerations

8.1 Climbing lanes

8.1.1 General remarks

Sections of motorway with lengthy longitudinal gradients have a considerable influence on the quality of the traffic flow and therefore on road safety. The introduction of climbing lanes on such ascending gradients

- separates fast and slow-moving traffic,
- improves the quality of the traffic flow, and
- reduces accident figures.

Climbing lanes are lanes that are added to carriageways on ascending gradients in order to widen them by a single lane.

8.1.2 Criteria for use

The following influencing variables are significant to the design of climbing lanes:

- traffic volumes,
- traffic composition,
- standard cross-section,
- progression of the gradient (or long section), and
- targeted level of service.

Climbing lanes may be necessary in situations where the longitudinal gradient, s, is greater than 2.0 %.

They are necessary when the level of service on the ascending gradient falls below level D according to the HBS.

Moreover, the introduction of climbing lanes must be considered if one or more of the following conditions are met:

- The level of service on the ascending gradient is worse than level C.
- The level of service on the ascending gradient is more than one level worse than the stretch of motorway preceding it.
- The economic benefits outweigh the additional costs.

8.1.3 Designing climbing lanes

On motorways, the length of a climbing lane should not fall below:

$$L_{ZFS} = 1{,}500 \text{ m} \qquad (18)$$

If necessary, they should be extended back beyond the start and beyond the end of the ascending gradient.

If the distance separating consecutive climbing lanes falls below 2,500 m, the climbing lanes should be combined for reasons of road safety. Climbing lanes on ascending gradients should not end at junctions.

To ensure that all lanes are used evenly, climbing lanes should be inserted into the carriageway on the inside of the through carriageway. On new build projects, the carriageway should be widened by aligning a specific axis for the affected carriageway or for both carriageways. In this case, the carriageway is widened by tapering the left-hand edge of the carriageway into the correspondingly widened central reserve over a distance of 60 m (Fig. 66).

When reconstructing or improving existing motorways, the insertion of climbing lanes is, as a rule, only possible on the outside of the existing carriageway. In these cases, the carriageway is widened by a gradual tapering of the right-hand edge of the carriageway and the climbing lane is introduced on the inside of the carriageway using markings (Fig. 66).

The tapering of the right-hand edge of the carriageway should be at least 200 m long.

In exceptional cases where an entry is situated on an ascending gradient, the climbing lane can be introduced as a direct extension of the merging lane.

The width of the climbing lane, B, shall be 3.50 m.

Climbing lanes can also be inserted on the ascending gradients of three-lane carriageways.

As a rule, climbing lanes should end on the inside of the through carriageway on stretches of motorway offering a clear view ahead.

In new build projects, the tapering of climbing lanes is indicated by hatched markings over a tapering length of 120 m.

When reconstructing or improving stretches of motorway, the inner lane is tapered using a hatched marking that is 120 m long. The subsequent cross fall of the carriageway is then completed by tapering the outer edge of the carriageway over a distance of at least 200 m.

8.2 Lane reductions

When improving a motorway and increasing the number of lanes at the same time, changes in the cross-section are necessary in the transition from the improved section to the old section. Such changes in cross-section can be integrated either in the form of lane drops at exits (Section 6.4.3) or in the form of lane reductions.

In areas characterized by high traffic volumes (DTV > 30,000 vehicles/24 h and in one direction), lane reductions can result in a reduction of road safety. For this reason, they should only be implemented in cases where they are unavoidable.

Most lane reductions occur on the open road. They should be avoided at junctions.

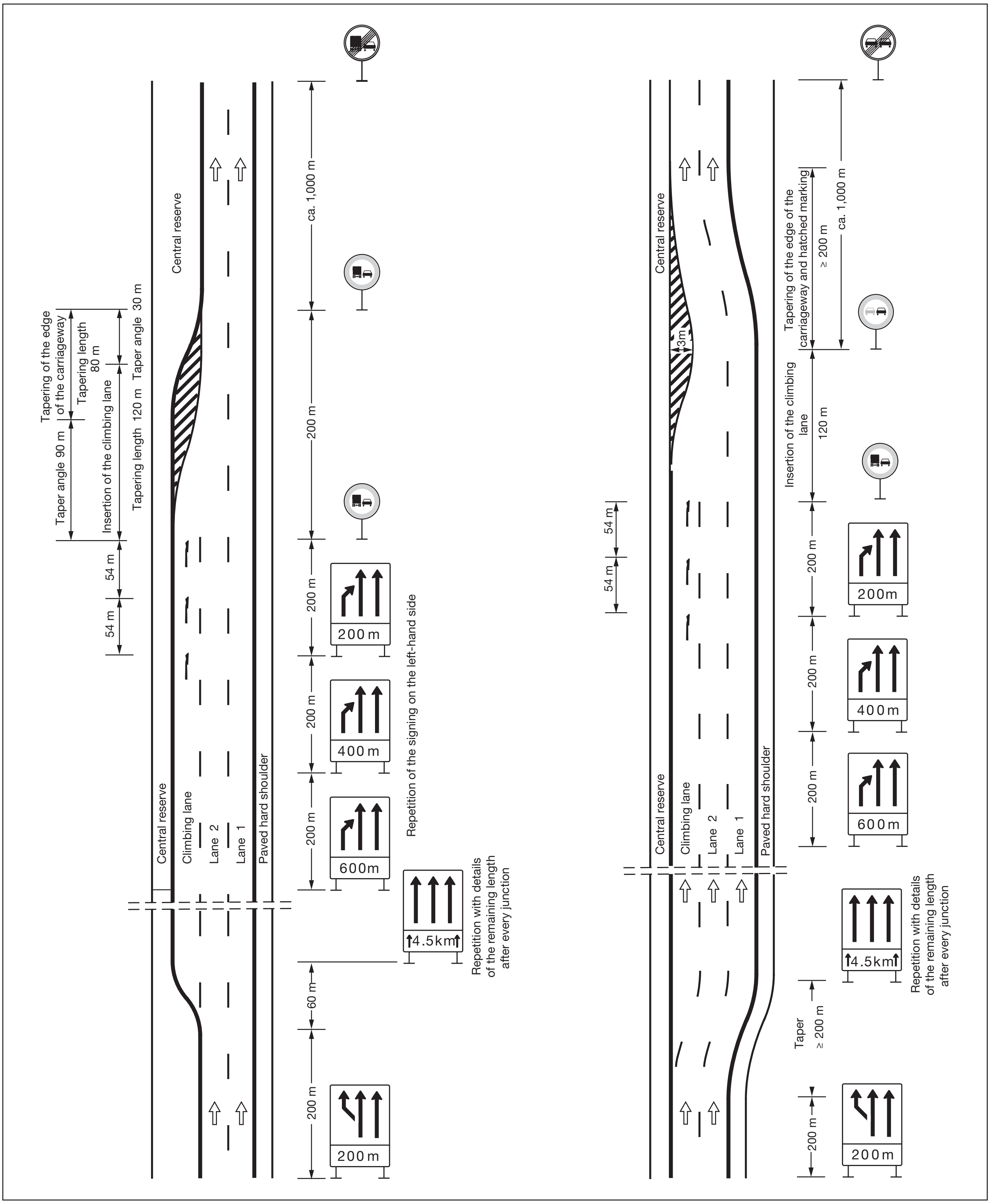


Fig. 66: Introduction of climbing lanes on a new build project (left) and when reconstructing or improving stretches of an existing motorway (right)

As a rule, it is the left-hand lane that is tapered for a lane reduction. Signs indicating that the road narrows up ahead (Z 531-21 StVO) are erected to alert drivers to the end of the lane. The geometric layout is the same as for the insertion of a climbing lane outlined in Fig. 66. The markings are applied in accordance with the Guidelines for Road Markings (RMS).

Where possible, lane reductions should be implemented on stretches of motorway offering a clear view ahead (i.e. straight alignment, flat gradient).

8.3 Central reserve crossing points

Crossing points are areas where the traffic can be moved across the central reserve during periods of construction.

Crossing points can be created for future use when constructing a new motorway or revising or improving an existing motorway or they can be created as the need arises on stretches of motorway that are in use.

It is recommended that crossing points should be planned ahead of

- motorway junctions,
- motorway bridges over valleys (with a length greater than 100 m),
- sections with a significantly different vertical alignment for both directional roadways, and
- tunnels.

In the case of tunnels in particular, crossing points should be established before the entrance to the tunnel in order to allow operational vehicles to change from one carriageway to the other.

In individual cases, for example on stretches of road characterized by high volumes of traffic, it may be expedient to situate central reserve crossing points upstream of junctions or at regular distances (greater than 5 km) on the open road.

Central reserve crossing points should be avoided on or under engineering structures and in the vicinity of junctions and staffed motorway service areas.

As a rule, the following crossing lengths apply (for a central reserve width of 4.00 m):

- two lanes: L = 135 m,
- three lanes: L = 220 m.

This allows lanes measuring 3.75 m in width and separated by a separation strip to be safely carried across the central reserve (Fig. 67).

This results in radii, R, of 350 m for s-shaped crossings on straight stretches of motorway, which in turn allow vehicles to travel at 80 km/h safely (V_{zul} = 80 km/h).

Other tapering lengths may be necessary in the approach to tunnels as a result of the widening of the central reserve.

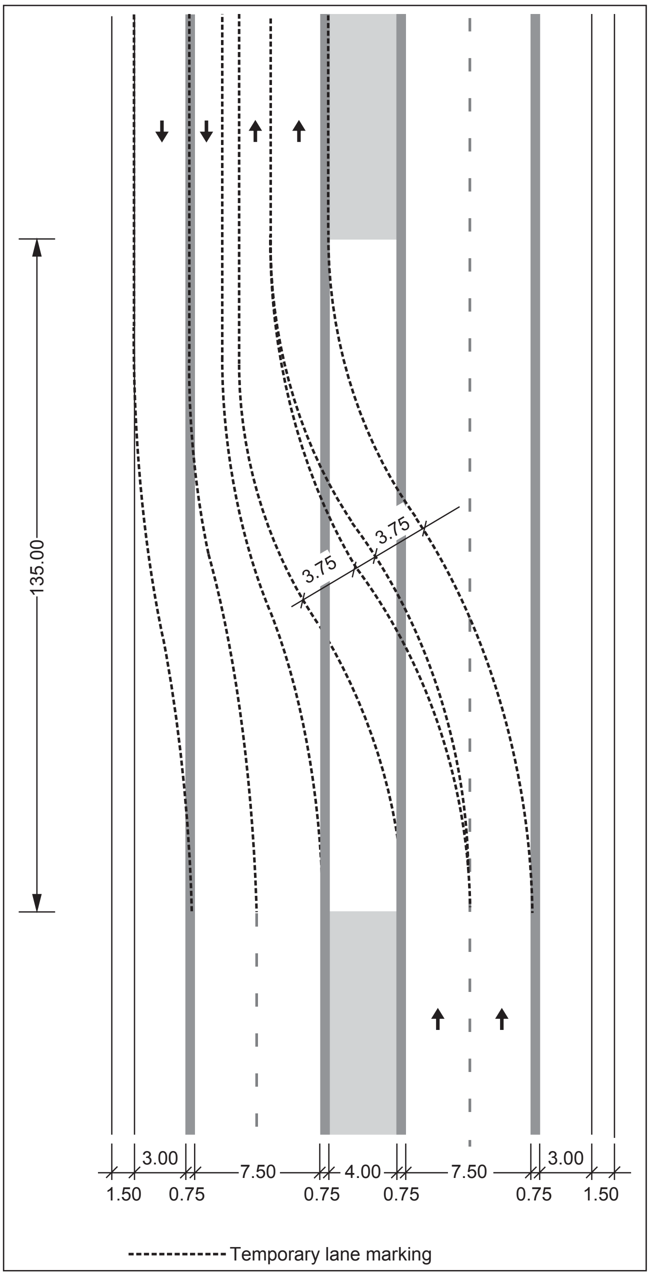


Fig. 67: Central reserve crossing point when two lanes are carried across the central reserve on a standard cross-section RQ 31 (dimensions in [m])

The limits of the crossings must be straight and perpendicular. The layout of vehicle restraint systems in these areas is regulated by the RPS.

Central reserve crossing points should only be established in places where the difference between the crossfall of the carriageway and that of the paved central reserve does not exceed 9.0 %.

In cases where a central reserve crossing point is situated in a circular curve and where one of the carriageways has a crossfall that slopes towards the inside of the curve, longitudinal drainage (box drains) will, as a rule, be necessary between the central reserve and the hardstrip.

Markings and signing for central reserve crossing points during construction periods are regulated by the Guidelines for Securing Roadworks on Roads *(Richtlinien für die Sicherung von Arbeitsstellen an Straßen*, RSA).

8.4 Special bridge considerations

8.4.1 General remarks

Bridges are constructed along motorways (A structures) or as overpasses along subsidiary roads over motorways (Ü structures).

In accordance with the standard DIN 1076, bridges have a clear span, LW, greater than or equal to 2.0 m. Culverts have a clear span, LW, less than 2.0 m. Culverts are not bridges and do not, therefore, require a log book for the structure, thereby reducing the amount of maintenance required.

Bridges require regular structural inspections and monitoring. For this reason, an appropriate maintenance route is necessary. These routes generally take the form of

- separate access points from the subsidiary network via parallel routes (A structures) or
- additional stopping areas before the abutment (Ü structures, animal crossings).

In the event of lane closures for longer structural inspections or maintenance work, central reserve crossing points must be provided in accordance with Section 8.3.

8.4.2 Designing the cross-section

As a rule, the cross-section of the open road is maintained on the bridge.

The standard cross-sections for motorway bridges are outlined in Section 4.5.

If, in exceptional cases, a footpath or a bicycle path has to be built along an A structure, the standard cross-section shall be designed in accordance with the standard cross-sections outlined in the RAL and the RiZ-ING.

For structures on subsidiary roads with cross-section dimensions that are not in line with valid regulations, it may be necessary to select a wider cross-section (standard cross-section in accordance with the RAL), taking predictable traffic developments into account.

Agricultural machinery must be taken into account when specifying the utilisable width of bridges on farm roads. Bridges on farm roads do not generally allow for two-way traffic, which means that a passing place is generally needed directly before the structure. For more detailed information, please refer to the Design Principles for Agricultural Roads associated with Construction Measures on Federal Trunk Roads *(Grundsätze für die Gestaltung ländlicher Wege bei Baumaßnahmen an Bundesfernstraßen,* edited by the Federal Minister of Transport BMV ARS 28/2003*).*

The clearance gauge for the road over which the bridge is constructed is the smallest height clearance at the critical point, taking structural settlement into account. This clearance gauge must be met.

8.4.3 Horizontal alignment

By making sure that the bridge and road crossings are as close to perpendicular as possible, the length of the structure and the structural design can be reduced in such a way as to make the design more economical. For this reason, an intersection angle of between 80 and 120 gon (72 and 108°) is recommended.

For reasons of economic efficiency, it is preferable to construct bridges on horizontal straights (e.g. because this allows for incremental launching). To ensure that the structure visually fits into the alignment of the open road, it can, in certain cases for which there are reasonable grounds, make sense to construct bridges in circular curves. In such cases, the radius of the circular curve should be as large as possible in order to ensure that the necessary crossfall is limited to

$$\max q = 5.0\,\% \qquad (19)$$

in order to allow for the installation of mastic asphalt.

The planning of bridges in transition curves should be avoided as a result of the continuous change in curvature.

There should be no changes in crossfall on bridges.

8.4.4 Vertical alignment

The gradient on a bridge should preferably be a constant longitudinal gradient.

In order to ensure highway drainage, the gradient shall, as a rule, be planned in such a way that a minimum longitudinal gradient, s, of 0.7 % shall be maintained on the bridge.

In areas where low and high points cannot be avoided there will be sections with small gradients, which will mean that adequate longitudinal drainage will not always be ensured. This results in shorter distances between the sections and therefore greater construction and maintenance requirements.

8.4.5 Drainage on bridges

On motorway bridges, drainage is generally interrupted before the abutment and the rainwater is shed to the side into rain reservoirs.

In individual cases, it may be expedient to use the cleaned rainwater to irrigate planted areas beneath the bridge.

In cases where there are reasonable grounds to do so, the drainage of the road section is carried along the bridge and through the abutment.

If, in exceptional cases, the bridge is situated in a sag, the surface water shall be drained away at the low point at the pier and channelled into rain reservoirs.

In those cases where the columns of flyovers are situated in the central reserve, the drainage of the central reserve shall be interrupted and channelled to the edge of the carriageway.

Bridge drainage pipes can be connected to the road drainage system. The positioning of a pipe from the overhead road, along the central column to connect up with the motorway drainage in the central reserve shall, however, be avoided.

8.4.6 Special structural considerations for bridges

A number of special requirements relating to the construction of bridges shall be taken into account during the design planning stage. These requirements include:

- the planning of parallel by-passes,
- the approval of any necessary by-passes or the introduction of single-lane, two-way traffic management,
- the position of the construction site facility,
- the alignment of construction roads and access roads,
- land acquisition considerations, especially for land that is only needed for extended time periods,
- the re-routing of watercourses through canals and the like and temporary structures in watercourses, including the necessary approvals,
- provisional drainage to the outfall for bridges that are constructed before the adjacent stretches of road have been completed, and
- necessary measures for conserving the ground water.

8.5 Special tunnel considerations

8.5.1 General remarks

Tunnels are engineering structures that pass under mountains, watercourses, or other obstacles. They can take a number of forms: longer, closed underpasses (L > 80 m), partially covered underground or overground roads, overground enclosed roads, and structures to protect against avalanches and falling rocks from above and the side.

Tunnels are planned in accordance with the Guidelines for the Equipment and Operation of Road Tunnels (RABT).

Experts should be consulted early and preliminary designs outlining the necessary technical equipment must be drawn up so as the operation technology requirements are adequately accounted for at the preliminary design stage.

8.5.2 Cross-section design

Tunnel cross-sections are outlined in Section 4.6. They are allocated to the standard cross-sections on the open road in accordance with Section 4.3 and the cross-sections in accordance with the RABT.

Depending on the construction method chosen, the width of the paved area can deviate from that of the standard cross-section of the open road because of special structural engineering considerations.

The construction method is selected on a case-by-case basis at the end of a comprehensive process in which the merits of various methods are weighed up, taking into consideration the geological, geometrical, and traffic engineering conditions as well as construction and operation costs.

The clearance height in tunnels can be restricted to 4.50 m if no technical equipment is to be installed over the carriageway.

Although 4+0 lane operation will not as a rule be required because of the increased ventilation and lighting requirements necessary for two-way traffic, it is possible should it be necessary. If it is implemented, evidence that the safety of tunnel users can be guaranteed must be supplied in accordance with the RABT.

8.5.3 Alignment

The most generously proportioned design elements should be used for the horizontal and vertical alignment of the tunnel. The minimum values given in Section 5 shall be observed.

Longitudinal gradients in tunnels, s, should always be limited to a maximum of 3.0 %. In the case of longer tunnels (L > 500 m), designers should aim for a maximum of 2.5 %.

Exceptions to this rule are tunnel sections of restricted length (L ≤ 200 m) on EKA 3 motorways, for which the maximum gradient of 6.0 % shall be observed (e.g. on slip road carriageways).

Saw tooth profiles with sudden changes of level around the central reserve shall be avoided in order to allow cross tunnels (cross-connecting passages between the two tunnel tubes) to offer barrier-free accessibility. Alternatively, a sudden change in the gradient of the inside edges of the carriageways is possible.

8.5.4 Special construction- and system-related tunnel considerations

Among others, the following technical design and operation aspects shall be taken into account when planning tunnels:

- traffic engineering equipment (e.g. static signs, variable message signs, traffic control systems, necessary construction heights, distances to planned booster fans),
- overall safety concept (e.g. safety documentation, risk analyses, co-ordination of alarm and hazard prevention plans with rescue services (fire brigade, police)),
- implementation of a speed limit in consultation with the traffic authorities, generally to Vzul equal to 80 km/h,

- selection of the carriageway surface at the tunnel portals with reflection properties to reduce transition lighting,
- avoidance of entries and exits at tunnels (EKA 1 and 2),
- ban on lane reductions in tunnels,
- positioning of emergency break down bays in tunnels where the length is greater than 900 m. (L ≥ 900 m),
- drainage from adjacent stretches of low areas to ensure outfall upstream of the tunnel.

The design of these and supplementary facilities such as tunnel operation buildings, emergency evacuation tunnels, supplies of water for fire-fighting purposes, and storage sumps for the collection of dangerous liquids and fuels spilled as the result of an accident or deluge for fire fighting are regulated by the RABT. In this regard, designers must ensure connection to access routes and storage areas.

8.6 Motorway service areas

There are two kinds of motorway service areas: staffed and unstaffed. Their layout and design is regulated by the Guidelines for Service Areas on Roads *(Empfehlungen für Rastanlagen an Straßen*, ERS).

When positioning motorway service areas, designers must make sure that the necessary signing does not overlap with the directional signing for motorway interchanges or junctions. For this reason, the distance between motorway service areas and interchanges must be in accordance with Section 6.2.

In order to ensure safe entry and exit, motorway service areas should be positioned on straight stretches of road. The entry and exit areas should be designed in accordance with the principles of interchange design (Section 6.4).

8.7 Lane operation around roadworks

It may become necessary to close individual lanes or carriageways to allow for maintenance work or in order to improve the motorway.

For the duration of the roadworks, lanes should be operated in accordance with the Guidelines for Securing Roadworks on Roads (RSA). In accordance with these guidelines, the number of lanes on the open road should be maintained through the roadworks.

In the interest of

- the safety of the personnel and the traffic in the works area and
- in order to avoid obstructing work,

the creation of a single temporary lane on the carriageway where the work is being carried out (e.g. in accordance with the 3+1 approach) should be avoided where possible.

Lane operations around road works are important considerations when it comes to specifying the width of the traffic space on motorways with the standard cross-section RQ 31 and on bridges along such motorways.

For reasons of traffic safety, mobile protective devices should as a rule be used to separate the streams of traffic moving in opposite directions around road works. To allow for this, a minimum carriageway width of 12.00 m is necessary during 4+0 temporary lane operation.

If the distance between the edge marking (Z 295 StVO) and the edge of the paved width is less than 0.20 m, the verge can be paved.

For information on the layout of central reserve crossing points, please refer to Section 8.3.

8.8 Hard shoulder running

Hard shoulders make a major contribution to both traffic flow and road safety and are an indispensible part of the motorway.

Nevertheless, in cases where EKA 1 motorways are congested, temporary use of the hard shoulder can be considered in order to increase capacity. This is, for example, the case when congestion or serious traffic disruptions occur on a regular basis that frequently result in rear-end collisions.

If hard shoulder running is to be implemented, the following aspects shall be taken into consideration:

- The average daily traffic volume should be at least 65,000 vehicles/24 h on two-lane stretches. In accordance with the HBS, evidence must be provided that the traffic flow quality level D is not reached for over 30 hours in the year on the section under consideration.
- Capacity bottlenecks are caused by the cross-section on the open road. Interchanges should be able to absorb the traffic volumes generated by hard shoulder running.
- Motorway interchanges, junctions, motorway service areas, and rest areas with toilet facilities must have merging and diverging lanes even when the hard shoulder is opened to traffic. Consideration can be given to the closure of minor rest areas with parking spaces for the duration of the hard shoulder running.
- Hard shoulders must be able to withstand the load exerted by heavy goods vehicles.
- The marking on the cross-section must be changed or the cross-section must be widened in such a way that all lanes and/or hard shoulders that are considered for truck traffic are at least 3.50 m wide and that it is not possible for vehicles to drive on the outer edge. All remaining lanes must be at least 3.25 m wide.
- For breakdown vehicles, emergency break-down bays (as a rule with emergency telephones) outside the through carriageway are necessary at intervals of

max. 1,000 m. The length of the emergency lay-by including tapers, L, should be 80 m long. Emergency break-down bays including hardstrips should be 3.00 m wide.
- The applicable speed limit shall be determined in consultation with the traffic authority.

Hard shoulder running that is restricted to certain times of the day has advantages over a permanent change in markings in terms of road safety, traffic flow, and road operation services.

BMV ARS 20/2002 contains additional information on legal issues related to traffic and approval, on issues related to structure and operation, as well as sample implementation plans for the positioning of variable message signs for hard shoulder running that is restricted to certain times of the day. The positioning of the sign 223 StVO is regulated by Section 41 VwV-StVO.

8.9 Maintenance access roads

8.9.1 General remarks

According to Section 1(4)(4) Federal Highway Act (*Bundesfernstraßengesetz*, FStrG), maintenance access roads are ancillary facilities that are mainly used for tasks executed by the road administration for federal trunk roads. They provide road operation services with opportunities to turn, even between distant junctions, and help reduce the number of empty trips and lost time.

8.9.2 Selecting locations

The establishment of maintenance access roads depends on the location of motorway maintenance depots (AM) and on the length of the section of the network for which they are responsible.

Maintenance access roads can be established:

- directly at motorway maintenance depots and stations that are not situated at junctions,
- at the border between the areas of responsibility of two motorway maintenance depots,
- in order to ensure an area of overlap between two bordering snow clearance areas,
- at three-way and four-way motorway interchanges,
- between two distant junctions, and
- on critical stretches of motorway.

On critical stretches of motorway that require a lot of winter weather-related maintenance, reduced-length snow clearance areas may be necessary. In such cases, designers should consider positioning maintenance access roads at the start and the end of the relevant stretch of motorway. Depending on the length of the stretch of motorway, consolidation of access roads should be considered.

Maintenance access roads shall preferably be established in locations where the existing infrastructure can be used, e.g. near crossings of the secondary road network.

They should be avoided

- at motorway service areas because parked vehicles can obstruct service vehicles and
- at topographically unfavourable locations with considerable differences in heights between the road and the surrounding terrain.

The junctions connecting the maintenance access roads to the motorway shall be designed in such a way that road safety and traffic flow on the through carriageway are hampered as little as possible. In order to ensure that this is the case, designers shall

- ensure adequate sight distance to overview the main line traffic at the point where the maintenance access road enters the motorway,
- carefully check the location of the maintenance access road in terms of its effects on the traffic on the through carriageway,
- allow for sufficient distance between the maintenance access road and the merging or diverging lanes at upstream or downstream junctions,
- allow for the necessary acceleration and deceleration processes of operational vehicles turning into or off the motorway outside the through traffic lanes (as a rule, existing hard shoulders or additional merging or diverging lanes), and
- give precedence to locations with the flattest possible longitudinal gradient on the through carriageway.

8.9.3 Technical design information

The winter maintenance vehicle (large 3-axle truck with very wide front-mounted snow plough) shall be used as the **design test vehicle** for maintenance access roads.

Information on swept paths can be found in the guideline Design Test Vehicles and Swept paths for Checking the Serviceability of Traffic Areas *(Bemessungsfahrzeuge und Schleppkurven zur Überprüfung der Befahrbarkeit von Verkehrsflächen).* To simplify the procedure, the swept paths of a 3-axle truck with an appropriately wide attachment shall be used for a winter maintenance vehicle.

Because of the low speeds involved, the maintenance access road is aligned on the basis of geometrical driving considerations.

As a rule, there is no need to take precautions for **encountering vehicles** .

As a rule, the **width of the carriageway** should be

$$B = 6 \text{ m (minimum value 5 m)} \qquad (20)$$

The carriageway width should not fall below this minimum value in order to ensure that vehicles can drive on or clear the maintenance access road even when visibility is poor.

The carriageway widths must be observed, even on bridges.

The maximum **longitudinal gradient** should be

$$s_{max} = 8\,\% \text{ (10 \% in exceptional cases)} \qquad (21)$$

Steeper longitudinal gradients can reduce road safety when carriageway conditions are poor (with snow and ice).

The connection of a maintenance access road to the motorway on a **slip road** is an exception. Because of its geometric design, the junction form resembles an at-grade T-junction.

In order to ensure good visibility and serviceability for both traffic movements, the connection between the slip road of the maintenance access road and the motorway carriageway should, where possible, be perpendicular. The amount of space needed for a traffic movement increases dramatically at skew junctions.

Adequate visibility must be ensured at maintenance access road junctions. To ensure adequate **approach sight distance** for the driver of a maintenance vehicle entering the motorway, the legs of the sight triangle should be at least 290 m, or even better, 400 m.

If maintenance access roads have to be connected to motorway sections without hard shoulders then structural modifications are needed in order to ensure safe turning on and off manoeuvres. The length of the necessary merging and diverging lanes shall be determined using the so-called design heavy vehicle and must be sufficient to allow a winter maintenance vehicle to reach at least the snow clearance speed of 30 km/h outside the flowing traffic. As a rule, a minimum merging lane length of

$$L_{min} = 50 \text{ m} \qquad (22)$$

is necessary. Depending on the longitudinal gradient and the target speed that needs to be reached, different values may be used.

8.9.4 Maintenance access road equipment elements

Maintenance access road elements include

- markings,
- signing,
- traffic guidance devices, and
- other equipment elements.

The **markings** on the motorway in the vicinity of the junction shall not be modified because general traffic is not permitted to drive on maintenance access roads.

Markings in the vicinity of maintenance access road slip roads (e.g. lines offering guidance or edge markings) are not necessary.

If a maintenance access road is connected to the subsidiary secondary network or an agricultural road, it must be made very clear that general traffic is not permitted to enter the maintenance access road. This can be done using a solid edge marking along the edge of the carriageway on the public road.

Signing must be used to make it clear that general traffic may not use the maintenance access road. The provisions of the German Highway Code (StVO) apply.

Traffic guidance devices such as marker posts and directional signs are not, as a rule, necessary. The erection of marker posts shall only be considered in exceptional cases on sections of maintenance access roads that are curvy and where the way ahead is not clear, e.g. in cases where part of the maintenance access road runs along a farm or forestry road.

Passive protective devices along the motorway shall be interrupted around the maintenance access road junction in accordance with the RPS, as is the case with T-junctions.

Other equipment elements will be necessary if

- the maintenance access road is to be locked in order to prevent it from being used unlawfully by general traffic,
- the noise mitigation effect is to be maintained when connecting the maintenance access road to a stretch of motorway with noise barriers or embankments (e.g. staggered arrangement of the structures, doors (or gates) that close automatically),
- cattle grids are to be installed along a stretch of motorway with game fences in order to ensure continuous protection against crossing animals.

8.10 Drainage

8.10.1 General remarks

Motorways should, where possible, be drained by means of surface drainage. This means that the surface water is shed towards the outside edge of the carriageway over the verge and into shallow surface channels or the soil.

In many cases, sub-surface drainage may be necessary, e.g. in situations where

- there is no permeable soil,
- the motorway runs through a protected drinking water area that requires such drainage, or
- the crossfall of a carriageway in curves leans to the central reserve.

In such cases, the surface water at the edge of the paved width is shed into gutters and kerbs and then channelled into rain reservoirs via pipelines or drainage channels. Once in the rain reservoir, the water is filtered using oil separators and sediment traps and is emitted gradually to the discharge system. Alternatively, the water can be allowed to infiltrate the soil.

The dimensions of the drainage equipment are determined in accordance with the Guidelines for Highway Design: Drainage (RAS-Ew) and the ATV regulations by the DWA = German Association for Hydrology, Sewage and Waste Material (ATV = General Technical Contract Conditions).

The scope of the necessary measures in protected drinking water areas is specified in accordance with the Guidelines for Construction Measures on Roads in Water Protection Areas (RiStWag).

When selecting and positioning drainage equipment, designers shall take not only technical drainage requirements but also road safety considerations and road maintenance service requirements into account. Accordingly, the information below shall be considered supplementary to the relevant drainage regulations.

8.10.2 Kerbs and gutters

If a kerb is necessary, it should be established at the edge of the gutter in the lateral safety area and should, as a rule, take the form of a flush kerb. It shall be positioned at least 0.75 m (EKA 1) or 0.50 m (EKA 2 and 3) from the lane.

On slip road cross-sections, kerbs shall be situated at least 0.50 m from the lane. Alternatively, the gutter can be positioned in such a way that the width of the verge is reduced.

In the central reserve, the gutter is, as a rule, positioned beside the hardstrip, reducing the width of the central reserve.

The standard height of flush kerbs is 0.07 m, of (if unavoidable) raised kerbs 0.12 m, and on bridges 0.15 m. The specifications in the RABT apply in tunnels.

In those cases where kerbs are required in front of vehicle restraint systems, flush kerbs are required.

8.10.3 Gullies and chambers

Gullies can be positioned directly in the gutter or alongside it in separate gully bays .

Gully bays have the advantage that the gullies are not driven over by heavy vehicles in periods of 4+0 lane operation in workzones and, therefore, will not be damaged. On the other hand, they require time-consuming cleaning and winter maintenance because they can only be cleaned or cleared of snow manually.

Inspection chambers, in particular in central reserves, shall be planned in such a way that they remain readily accessible even after the installation of passive protective devices. For this reason, the beams on crash barriers should not be positioned above inspection chambers.

8.10.4 Pipelines

The position and installation depth of pipelines shall be planned in such a way that they cannot be damaged by the installation of crash barriers (or during their subsequent repair). This is particularly true for those in the central reserve.

8.10.5 Drainage at the foot of a slope

Shallow surface channels or ditches on embankments or in cuts shall be installed in grown soil at the foot of slopes. The width of a berm ditch between the verge and the slope is determined by hydrologic calculations.

Drainage hutches are, as a rule, 2.00 m wide. However, they can be wider on carriageways with more than two lanes.

In the transition area between a cut and an embankment, the drainage hutch must be narrowed because of the difference of its position in the cross-section of the cut or the embankment.

8.11 Operation of the construction site

Important preparations must be made during the design planning stage in order to ensure that construction can begin promptly and that construction will be economical. Among others, such preparations include:

- space for site offices and grounds, roads for on-site transportation, and the deposit of topsoil (temporary usage),
- identification of space for borrow pits including access,
- identification of temporary dumps, which are necessary during construction, for soil that is not required,
- planning of the construction phases with the necessary diversion of traffic, and
- any necessary closures of public roads and ways, as well as the signing of diversion routes.

9 Summary of operation and design features

Table 26: Summary of operation and design features

Design class	**EKA 1 A**	**EKA 1 B**	**EKA 2**	**EKA 3**
Operation features				
Network function	Long-distance motorway	Inter-regional motorway	Motorway-like road	Urban motorway
Speed limit	None			V_{zul} = 100 km/h
Lane operation around construction works	4+0 generally necessary		4+0 not necessarily needed	
Design features				
Cross-section	Dual carriageway			
	RQ 43.5 RQ 36.0 RQ 31.0		RQ 28.0	RQ 38.5 RQ 31.5 RQ 25.0
Alignment				
Horizontal alignment				
Maximum length of the straights L [m]	2,000			
Minimum curve radius R [m]	900	720	470	280
Minimum clothoid parameters A [m]	300	240	160	90
Minimum curve radius in the case of a crossfall to the outer edge of the curve R [m]	4,000			1,000
Vertical alignment				
Maximum longitudinal gradient s [%]	4.0	4.5	4.5	6.0
Minimum crest diameter (H_K) [m]	13,000	10,000	5,000	3,000
Minimum sag diameter (H_W) [m]	8,800	5,700	4,000	2,600
Sight distance				
Stopping sight distance (s=0 %) Sh [m]	250			110
Design of the roadway surface				
Minimum crossfall q [%]	2.5			
Maximum crossfall in curves q [%]	6.0			
Maximum relative grade max Δs [%]	0.9 (a ≥ 4.0 m) 0.225 · a (a < 4.0 m)			0.9 (a ≥ 4.0 m) 0.25 · a (a < 4.0 m)
Minimum relative grade min Δs [%]	0.10 · a			
Junctions	Grade-separated			
Recommended junction spacing	> 8,000 m	> 5,000 m		none

Appendix 1

Options when routing an urban motorway through a densely built-up area

When an EKA 3 motorway route corridor needs to be linked to the developments alongside it, parallel access roads must be built. There are a variety of standard solutions for the cross-section arrangements (see Fig. 68 and Fig. 69). The differences between these solutions relate to:

- their width development,
- the level of the urban motorway,
- the complexity of the structure (uncovered, partially covered, completely covered), and
- the noise control measures used.

Completely covering the depressed carriageway of an urban motorway must be avoided as emission control generates high construction and maintenance costs. Legal problems can also arise. The increased operation costs associated with tunnels and covered roads must also be taken into consideration.

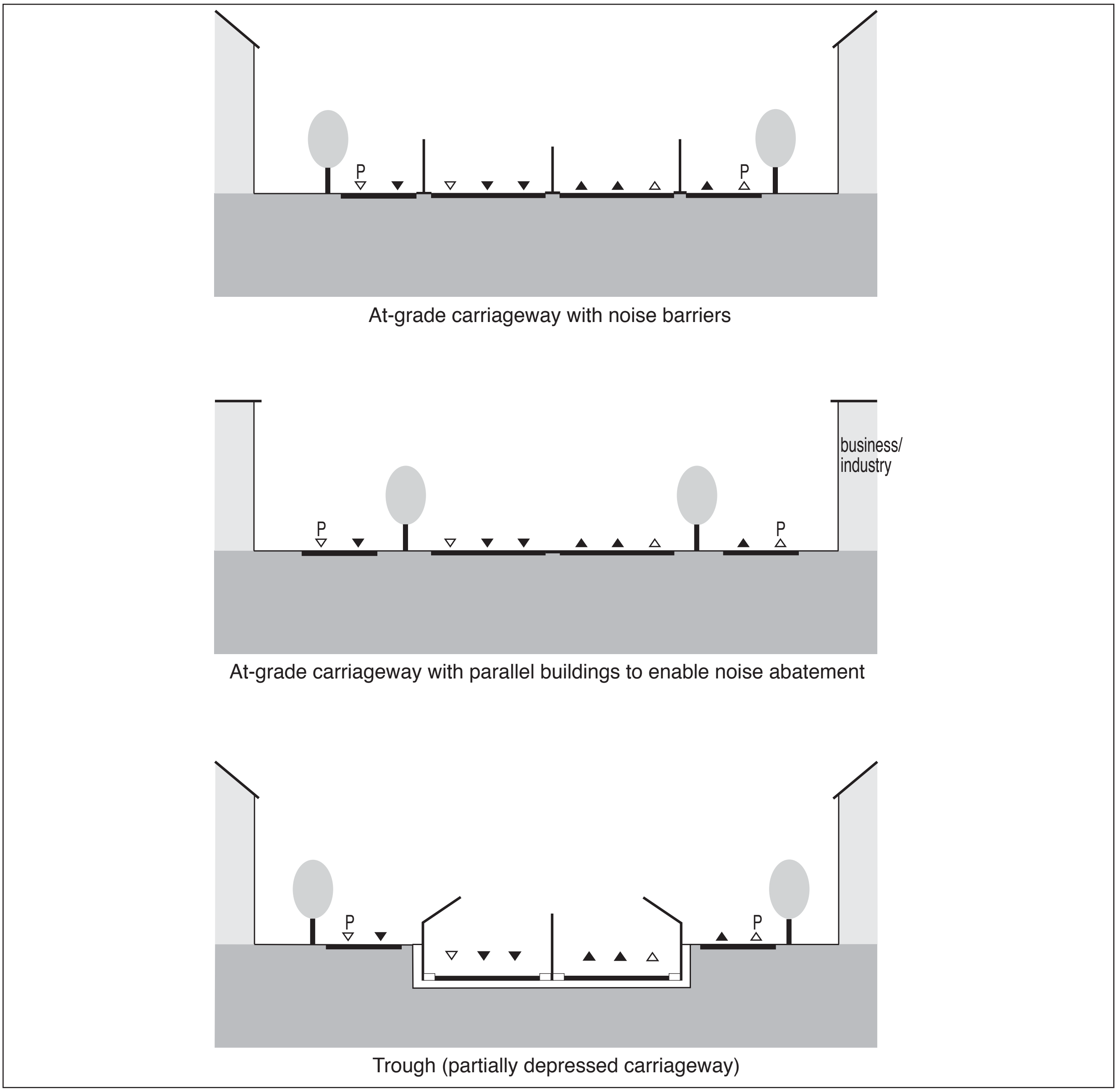


Fig. 68: Cross-section solutions for urban motorways with parallel local roads (schematic diagram, details of equipment are not included): at-grade and partially depressed carriageways

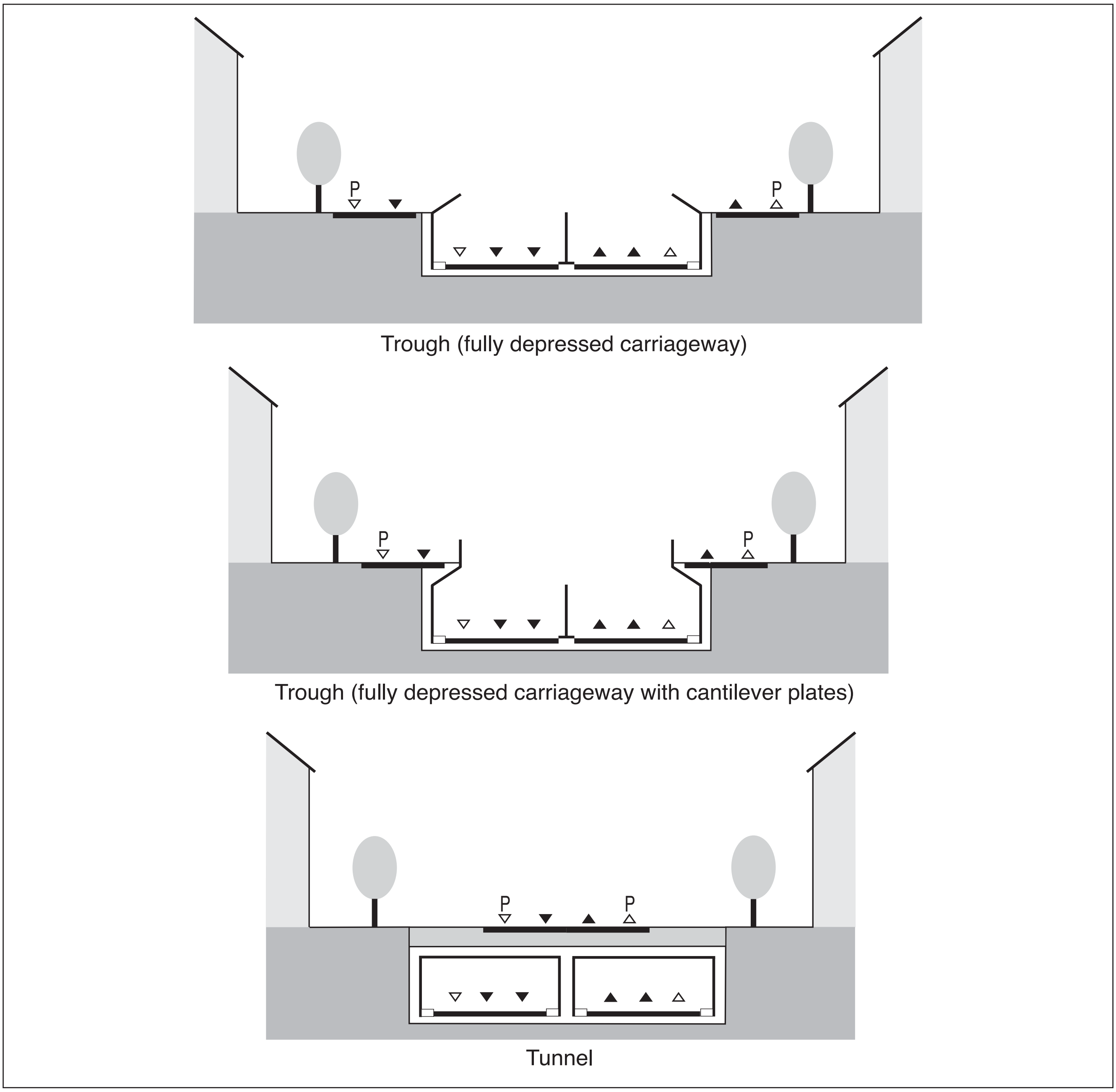


Fig. 69: Cross-section solutions for urban motorways with parallel local roads (schematic diagram, details of equipment are not included): fully depressed carriageway

Appendix 2

Traffic management (lane operation) and road widening approaches when widening a motorway from four lanes to six

When a motorway is widened, it is generally widened along the existing line. In exceptional cases, e.g. when a particularly sensitive area has to be avoided or when engineering structures are constructed in valleys, deviations from the given route corridor are possible.

In principle, when improving a four-lane motorway and simultaneously widening it to six lanes, one of three approaches can be chosen:

- full asymmetrical widening,
- partial asymmetrical widening, and
- symmetrical widening.

The full asymmetrical widening of a motorway (Fig. 70) involves two construction phases:

Phase 1: 2+2 lane operation on the existing carriageway, construction of a new carriageway alongside the existing cross-section.

Phase 2: 4+0 lane operation on the completed new carriageway, deconstruction of the old total cross-section and construction of a second, new carriageway.

End of project: Traffic shifted to 3+3 lane operation.

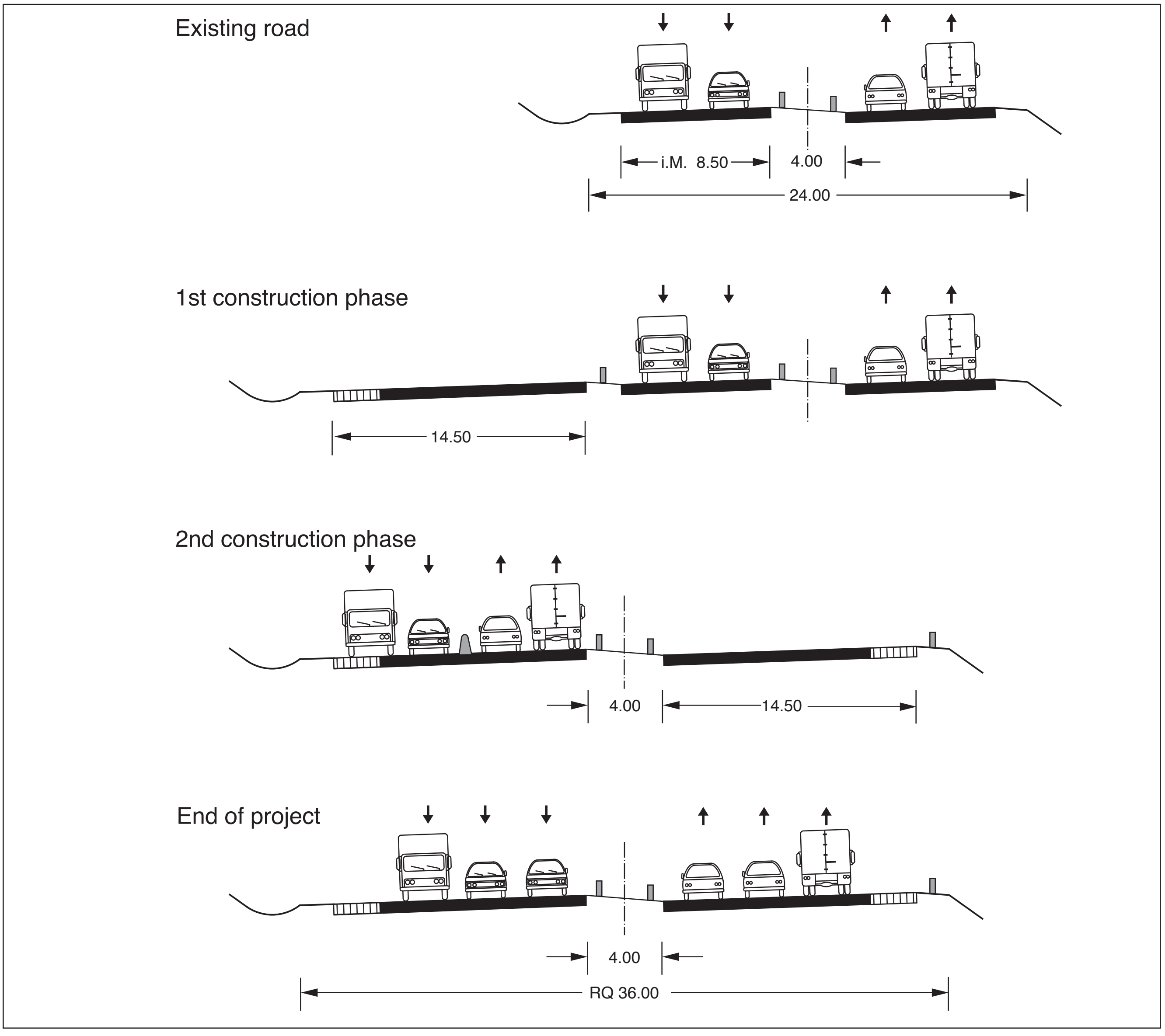


Fig. 70: Full asymmetrical widening (dimensions in [m])

In cases characterized by structural restrictions or a shortage of available space, the partial asymmetrical widening approach can also be considered. This approach requires an additional construction phase because one carriageway has to be provisionally widened immediately to allow for temporary 4+0 lane operation (Fig. 71).

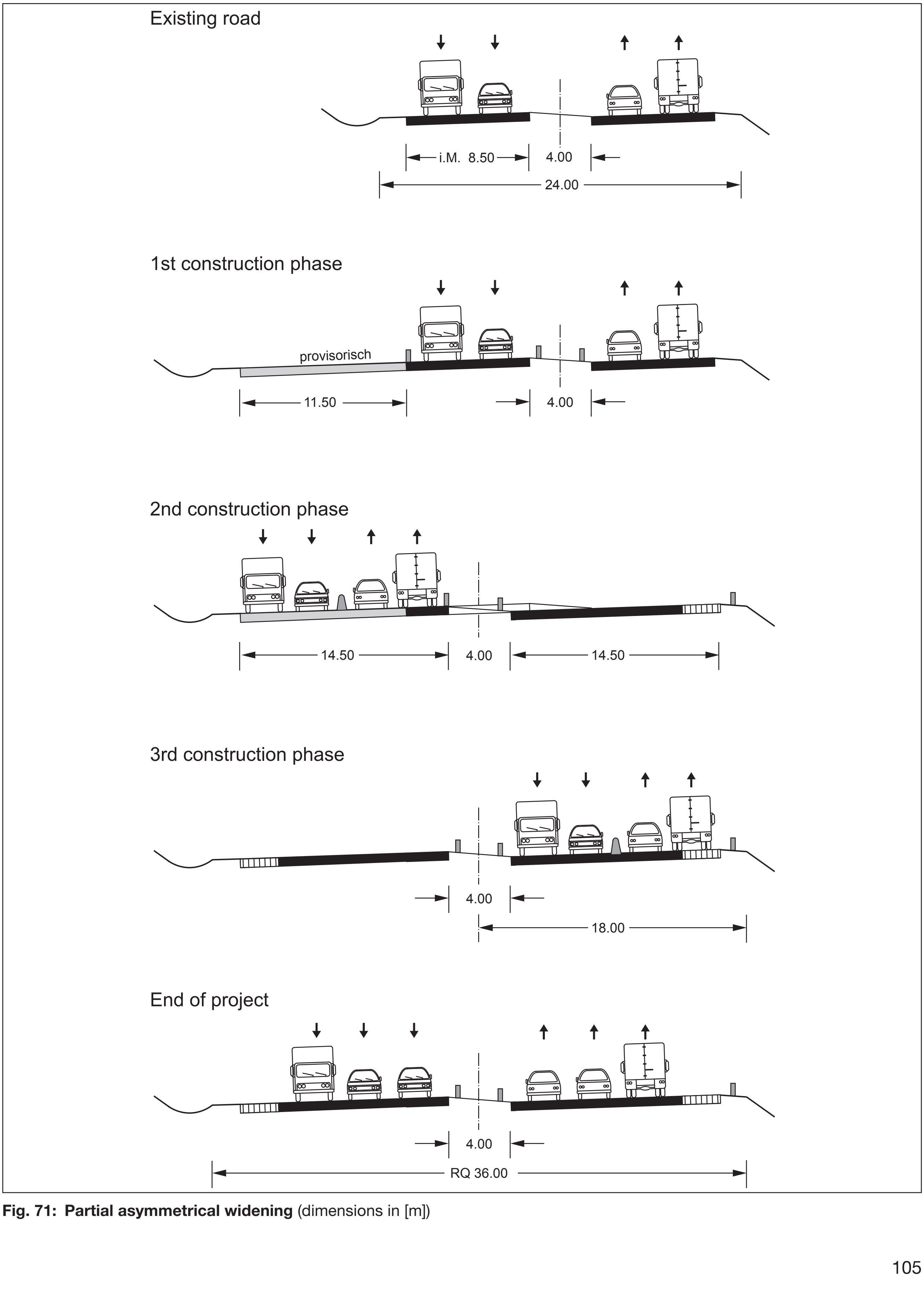


Fig. 71: Partial asymmetrical widening (dimensions in [m])

The symmetrical widening approach (Fig. 72) always requires interim provisional carriageways and consequently involves three construction phases.

Phase 1: 2 (normal) + 2 (restricted) lanes open to traffic on the existing carriageways; provisional widening of one carriageway.

Phase 2: 4+0 lane operation on the provisionally widened carriageway, deconstruction of the old carriageway and construction of the first new carriageway.

Phase 3: Traffic shifted to 4+0 lane operation on the finished carriageway, deconstruction of the second old provisional widened carriageway, and construction of the second new carriageway.

End of project: Traffic shifted to 3+3 lane operation.

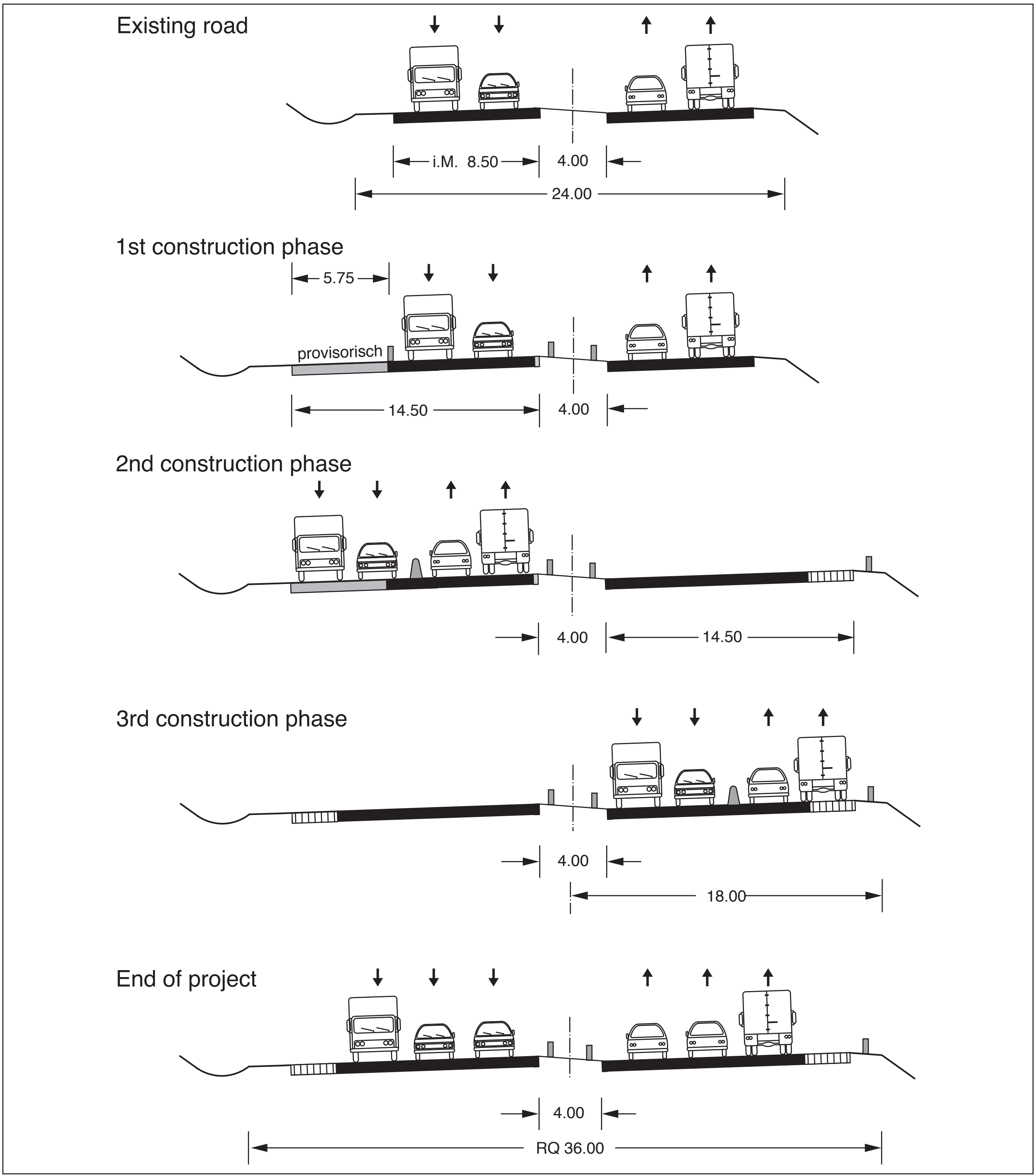


Fig. 72: Symmetrical widening (dimensions in [m])

The full asymmetrical approach to road widening has the advantage that it

- only comprises two construction phases,
- causes less traffic disruption, and
- involves shorter construction periods.

However, it requires the axis to be moved from its original position, which means that more space is needed. In terms of construction technology and traffic engineering, this approach results in an excessively wide central reserve or an excessively wide verge. For this reason, it is mainly considered for roads with narrow original cross-sections.

If the cross-section of the road is wide, the symmetrical widening of the road generally allows for temporary four-lane traffic and sufficient space for the highway works. The shifting of the axis is not necessary in this case.

The selection of the widening approach must consider all the factors. A choice can, therefore, only be made on a case-by-case basis, taking all marginal conditions for each case into consideration. The following factors play a decisive role in this process:

- the horizontal and vertical alignment,
- the topography,
- the type and number of engineering structures, the distances between them, junctions, and ancillary facilities, and
- the type of sensitive areas affected by the road or located alongside the road and the distances separating them.

Table 27 contains a selection of criteria and how their impacts swing the balance in favour of a particular widening approach.

Table 27: The impact of selected marginal conditions on the choice of widening approach when widening a motorway from four lanes to six

	Asymmetrical	**Symmetrical**
	widening approach	
Short distance between constraints	–	+
Possibility of having to widen existing overpasses	–	+
Existing overpasses are too narrow for provisional 4+0 lane operation	+	–
Underpasses are in need of rehabilitation	+	–
A change in gradient is necessary	+	–
Introduction and amendment of provisional lane operation	+	–
Difficult to access the highway works from outside	+	–
Dissection of forest areas	+	–
Costs	○	○
Construction period	+	–
Space required	–	+

\+ conducive/possible
○ decision must be made on a case-by-case basis
– not conducive/not possible

Appendix 3

Calculation of minimum curve radii (see Section 5.2.2)

The equation below is used to calculate minimum curve radii for

- open roads,
- slip roads in junctions, and
- curve radii with crossfalls to the outside of the curve.

$$\min R = \frac{V^2}{3{,}6^2 \cdot g \cdot (\max f_R \cdot n + q)} = \frac{V^2}{127 \cdot (\max f_R \cdot n + q)}$$

where

min R [m] = minimum curve radius
V [km/h] = speed
g [m/s²] = gravitational acceleration (9.81 m/s²)
a [m/s²] = transferrable braking deceleration (3.7 m/s²)
max f_T [-] = tangential coefficient of adhesion
μ_{SKM80} [-] = skid resistance value measured using the SKM skid resistance measurement procedure at V = 80 km/h (threshold value in accordance with M BGriff)
max f_R [-] = maximum radial coefficient of adhesion = 0.925 · max f_T
n [-] = utilization coefficient (utilization of the maximum radial coefficient of adhesion)
n = 0.40 (open road, q = 6.0 %)
n = 0.50 (slip road carriageway, q = 6.0 %)
q [-] = crossfall
min q [-] = minimum crossfall (q = 2.5 %)
max q [-] = maximum crossfall (q = 6.0 %).

The maximum crossfall of 6.0 % has proven suitable in practice for the construction of common wearing courses (exception: mastic asphalt). In exceptional cases, e.g. if it is impossible to avoid applying curve radii lower than the minimum, the crossfall, q, can be increased to 7.0 %. In this case, the maximum permissible incline, p, of 9.0 % must be observed.

The maximum mathematically possible tangential adhesion coefficient is based on the converted skid resistance measured values μ_{SKM} (threshold values) at a speed, V, of 80 km/h.

Table 28: Decisive adhesion coefficient f_T [-]

V	f_T (SRM_{1980})	$\mu_{SKM\,80}$	$f_{T,\,RAA}$
30	0.51	0.52	0.45
40	0.46	0.47	0.41
50	0.41	0.44	0.38
60	0.36	0.41	0.36
70	0.32	0.39	0.34
80	0.29	0.37	0.32
90	0.25	0.35	0.30
100	0.23	0.33	0.29
120	0.19	0.30	0.27
130	0.18	0.29	0.25

f_T(SRM_{1980}) [-] = tangential adhesion coefficient, measured using SRM (1980)
μ_{SKM80} [-] = skid resistance value measured using the SKM skid resistance measurement procedure at V = 80 km/h (threshold value in accordance with M BGriff)
$f_{T,\,RAA}$ [-] = tangential adhesion coefficient, RAA design principles ($f_{T,\,RAA} = 0.877 \cdot \mu_{SKM80}$)

Table 29: Minimum curve radii min R [m] (open road)

V	min R	
	q = 6.0 % n = 0.4	q = 2.5 % n = 0.1
80	280	930
90	370	1,200
100	470	1,500
120	720	2,300
130	900	2,700

Table 30: Minimum curve radii
min R [m] (slip roads at junctions)

V	min R	
	q = 6.0 % n = 0.5	q = 2.5 % n = 0.3
30	30	50
40	50	90
50	80	150
60	125	230
70	180	320
80	250	440

Table 31: Minimum curve radii
min R [m] for crossfalls to the outside of the curve

V	min R
	q = – 2.5 % n = 0.25
80	1,050
90	1,400
100	1,900
120	3,200
130	4,000

Geometry of the clothoid (see Section 5.2.3)

All clothoids are geometrically similar. This is why the same angles of direction change and the same form values or ratios, r/a = R/A etc. occur at the same form points (also known as characteristic points). They are uniquely defined by the radius r of the uniform clothoid (r = 1) for all clothoids (Fig. 73 and Table 32).

For the geometry of the clothoid, please refer to Fig. 74.

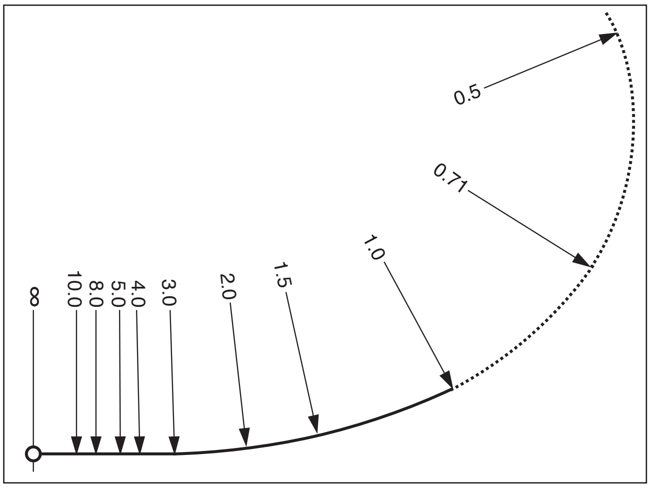


Fig. 73: Characteristic points of the clothoid

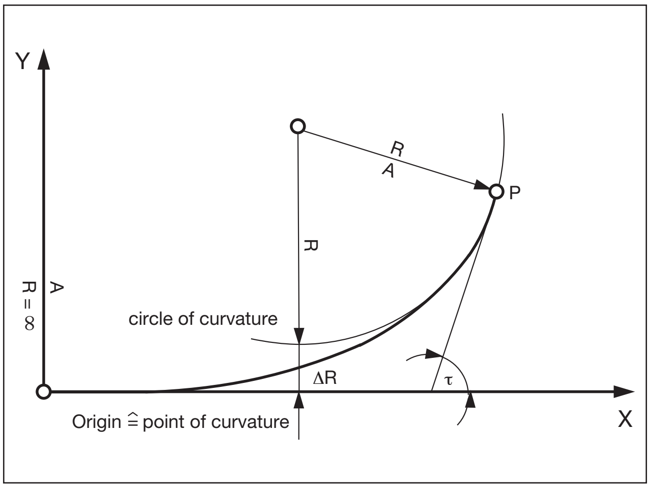


Fig. 74: Geometry of the clothoid

Table 32: Values of the clothoid characteristic points

Characteristic point r	τ [gon]	τ [rad]	A		R		L	
1	31.83	0.50	1.00R	1.00L	1.00A	1.00L	1.00A	1.00R
1.5	14.16	0.22	0.67R	1.50L	1.50A	2.25L	0.67A	0.45R
2	7.96	0.13	0.50R	2.00L	2.00A	v4.00L	0.50A	0.25R
3	3.54	0.06	0.33R	3.00L	3.00A	9.00L	0.33A	0.11R
4	1.99	0.03	0.25R	4.00L	4.00A	16.00L	0.25A	0.06R
5	1.27	0.02	0.20R	5.00L	5.00A	25.00L	0.20A	0.04R
6	0.89	0.01	0.17R	6.00L	6.00A	36.00L	0.17A	0.03R
∞	0.00	0.00	0.00	0.00	∞	∞	0.00	0.00
$\frac{R}{A}$	$\frac{100}{r^2 \cdot \pi}$	$\frac{1}{2 \cdot r^2}$	$\frac{R}{r}$	$r \cdot L$	$r \cdot A$	$r^2 \cdot L$	$\frac{A}{r}$	$\frac{R}{r^2}$

The formation law of the clothoid is:

$$A^2 = R \cdot L \qquad \text{(A 23)}$$

$$\tau\,[\text{rad}] = \frac{L}{2 \cdot R} \qquad \text{(A 24)}$$

$$\tau\,[\text{gon}] = \frac{L}{2 \cdot R} \cdot \frac{200\ \text{gon}}{\pi} \qquad \text{(A 25)}$$

$$X = \int_0^L \cos \frac{L^2}{2 \cdot R^2}\, dL \qquad \text{(A 26)}$$

$$Y = \int_0^L \sin \frac{L^2}{2 \cdot R^2}\, dL \qquad \text{(A 27)}$$

where

R [m] = radius of the circle of curvature at point P on the clothoid

A [m] = clothoid parameter

L [m] = length of the clothoid from the origin to point P

τ = angle between the tangents at the starting point and at point P

X, Y = rectangular co-ordinates of the point P

X_M = abscissa of the centre of the circle

Δ R [m] = distance of the circle of curvature from the tangent at the origin

For approximate calculations, the following approximation formulae expressed in L and R suffice for X, Y, and Δ R:

$$X \approx L \qquad \text{(A 28)}$$

$$Y \approx \frac{L^2}{6 \cdot R} \qquad \text{(A 29)}$$

$$\Delta R \approx \frac{L^2}{24 \cdot R} \qquad \text{(A 30)}$$

Appendix 5

Calculation of the crest and sag curve (see Section 5.3.2)

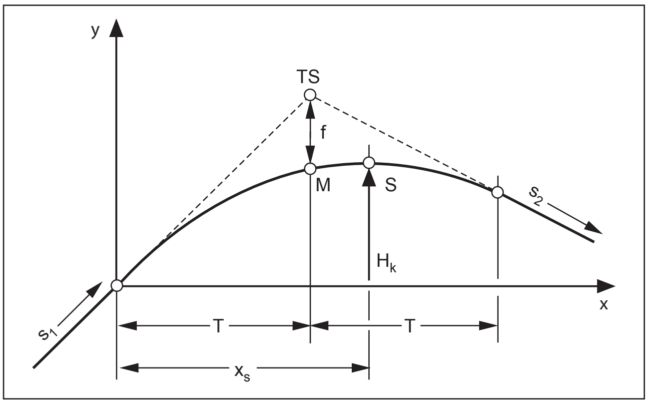


Fig. 75: Crest and sag curve with quadratic parabolic curve

$$x_s = \frac{s_1}{100} \cdot H \tag{A 31}$$

$$s(x) = s_1 + \frac{x}{H} \cdot 100 \tag{A 32}$$

$$y(x) = \frac{s_1}{100} \cdot x + \frac{x^2}{2 \cdot H} \tag{A 33}$$

$$T = \frac{H}{2} \cdot \frac{s_2 - s_1}{100} \tag{A 34}$$

$$f = \frac{T^2}{2 \cdot H} = \frac{T}{4} \cdot \frac{s_2 - s_1}{100} = \frac{H}{8} \cdot \left(\frac{s_2 - s_1}{100}\right)^2 \tag{A 35}$$

Rule of signs:

Ascending gradient:	positive ($+s_1$, $+s_1$)
Descending gradient:	negative ($-s_1$, $-s_1$)
Sag diameter (HW):	positive (+H)
Crest diameter (HK):	negative (–H)

H	[m]	Curve diameter (diameter of the summit arc of the quadratic parabolic curve)
T	[m]	Tangent length
s_1, s_2	[%]	Longitudinal gradient of the tangents
s(x)	[%]	Longitudinal gradient at a random point of the curve
y(x)	[m]	Ordinate of a random point
x_S	[m]	Abscissa of the crown
f	[m]	Random value of the point of intersection to the arc of the curve
M		Centre of the curve
S		Crown
TS		Point of intersection

Link between crest diameter and stopping sight distance (see Section 5.3.2)

The crest diameters in Table 15 (Section 5.3.2) are based on safety assumptions and specifications.

Basically, drivers on a crest should be able to see a stopped car (end of a queue on a congested motorway) at the earliest possible stage.

This means that to meet the stopping sight distance, evidence must be provided of visibility on crests from a driver's eye height to an object height, h_z, of 1.0 m.

Safety considerations such as the recognisability of vehicles at night or in fog (height of the head lights/brake lights, visible surface of the vehicles) or the perception and reaction behaviour of drivers on long/fast motorway journeys result in larger minimum crest diameters than would be necessary according to the requirements above for the visibility of the end of a queue.

Consequently, the minimum crest diameters given in Table 15 are the result of an object height of $h_z = 0.5$ m. The link illustrated in Fig. 76 applies.

If the minimum crest diameter is applied, there is no need to provide evidence that the stopping sight distance has been met. In this case, the evidence of the sight distance in the horizontal alignment suffices (Section 5.5).

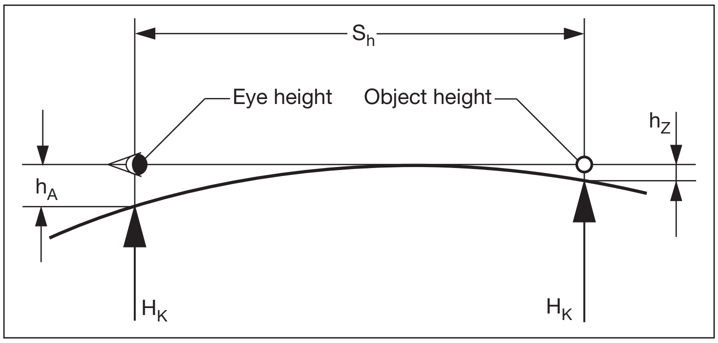


Fig. 76: Link between stopping sight distance and crest diameter

$$\min H_K = \frac{S_h^2}{2 \cdot \left(\sqrt{h_A} + \sqrt{h_Z}\right)^2} \qquad \text{(A 36)}$$

where
min H_K [m] = minimum crest diameter
S_h [m] = required stopping sight distance (Section 5.5, Fig. 18 and Appendix 7, Table 33)
h_A [m] = Eye height ($h_A = 1.0$ m)
h_Z [m] = Object height ($h_Z = 0.5$ m).

Appendix 7

Calculation of the stopping sight distance (see Section 5.5)

The stopping sight distance corresponds to the necessary stopping distance. It is calculated using the following equations:

$$S_h = S_1 + S_2 \qquad \text{(A 37)}$$

$$S_1 = \frac{V}{3.6} \cdot t_R \qquad \text{(A 38)}$$

$$S_2 = \frac{\left(\frac{V}{3.6}\right)^2}{2 \cdot g \cdot \left(f_T + \frac{s}{100\,\%}\right)} = \frac{\left(\frac{V}{3.6}\right)^2}{2 \cdot \left(a + g \cdot \frac{s}{100\,\%}\right)} \qquad \text{(A 39)}$$

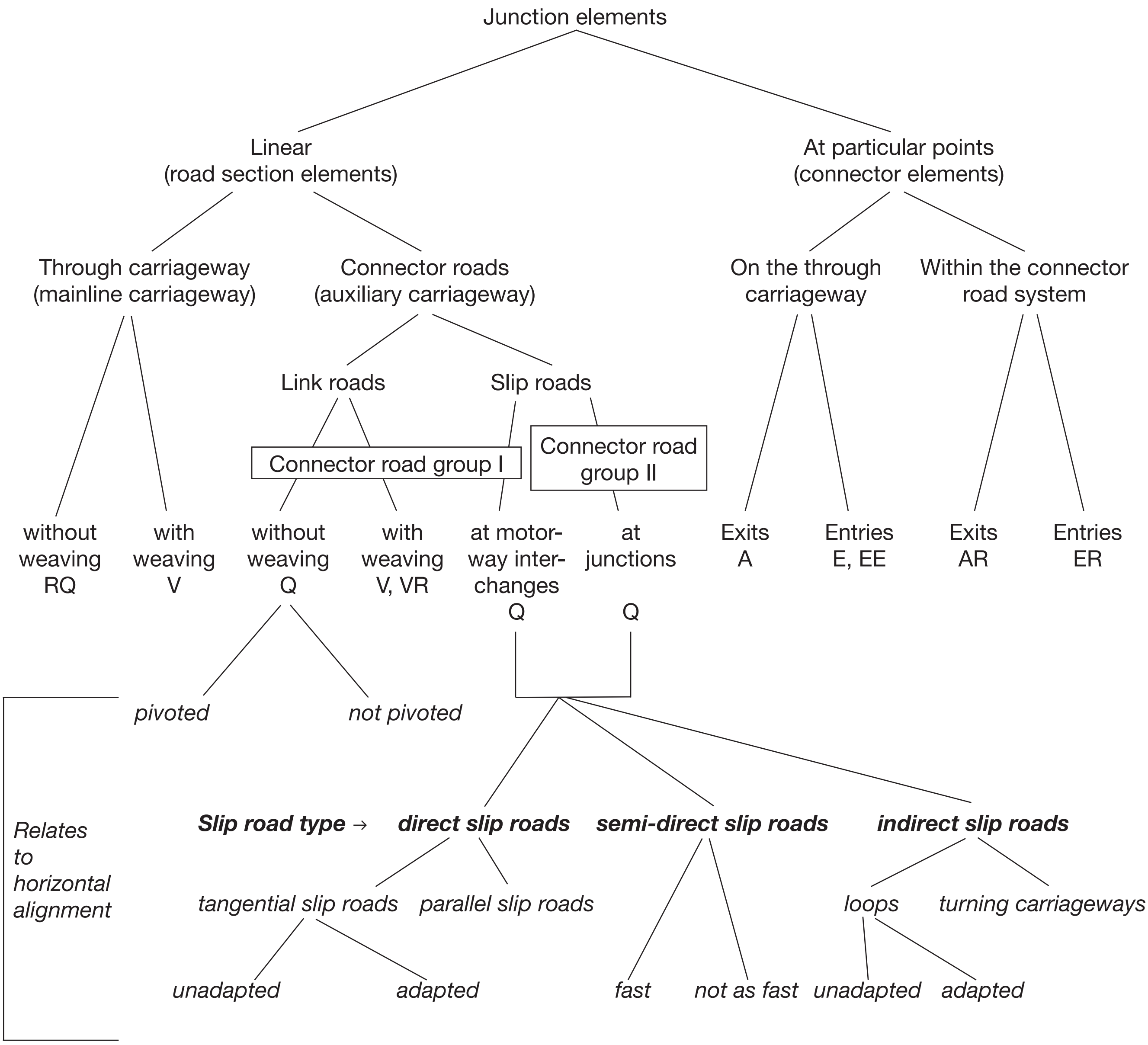
where

S_h [m] = stopping sight distance
S_1 [m] = distance travelled during the driver's reaction time and the vehicle's brake response time
S_2 [m] = braking distance
V [km/h] = speed
t_R [s] = driver's reaction time and the vehicle's brake response time (t_R = 2 s)
s [%] = longitudinal gradient
g [m/s^2] = gravitational acceleration (g = 9.81 m/s^2 = const)
a [m/s^2] = transferable braking deceleration (braking without ABS, mean braking deceleration, a = 3.7 m/s^2 = const)
f_T [–] = tangential adhesion coefficient

Table 33: Stopping sight distance S_h [m]

V [km/h] \ s [%]	– 5.0	– 4.0	– 3.0	– 2.0	– 1.0	0	1.0	2.0	3.0	4.0	5.0
30	27	27	27	27	26	26	26	26	25	25	25
40	41	41	40	40	39	39	38	38	38	37	37
50	58	57	56	55	55	54	53	53	52	51	51
60	77	75	74	73	72	71	70	69	68	67	66
70	98	96	94	93	91	90	89	87	86	85	84
80	121	119	117	115	113	111	109	108	106	105	103
90	147	144	142	139	137	134	132	130	128	126	125
100	176	172	169	166	163	160	157	155	152	150	148
110	207	202	198	194	191	187	184	181	178	175	173
120	240	235	230	225	221	217	213	209	206	202	199
130	275	269	264	258	253	248	244	240	235	232	228

Diagram of junction elements



Appendix 9

Technical standards and specifications

DIN[1), 2)]	DIN EN 1317	Protective Devices on Roads (various parts)
	DIN EN 12676-1	Anti-glare Screens for Roads – Part 1: Specifications and properties
	DIN EN 12676-2	Anti-glare Screens for Roads – Part 2: Test Procedures
FGSV[2)]		Design Test Vehicles and Swept Paths for Checking the Serviceability of Traffic Areas (FGSV 287)
	ERS	Recommendations for Service Areas on Roads (FGSV 222)
	ESAS	Recommendations for road safety audits (FGSV 298)
		Recommendations for the Design of Noise Control Facilities on Roads (FGSV 227)
	ESG	Recommendations on Designing Roads in Built-up Areas (FGSV 230)
	ESLa	Recommendations Regarding the Integration of Roads into the Landscape (FGSV 254)
		Design Principles for Agricultural Roads associated with Construction Measures on Federal Trunk Roads (FGSV 675/3).
	HBS	German Highway Capacity Manual (FGSV 299)
	HLB	The Code of Practice for the Positioning and Design of Vertical Traffic Guidance Equipment. In Straße und Autobahn 8 (1957), H. 6, p. 219–221
	HNL-S	Code of Practice for Environmental Conservation and Landscape Management in the Construction of Federal Trunk Roads (FGSV 246)
	HVA F-StB	Manual Concerning Contracts Governing the Services Provided by Freelance Engineers and Landscape Architects in the Construction of Roads and Bridges (FGSV 941)
		References on the Implementation of Landscape Management Compensation Measures in the Construction of Trunk Roads (FGSV 248)
	H ViSt	References on the Visualization of the Design of Rural Roads (FGSV 262)
		Information Sheet concerning Road Operation Services: Upkeep of Green Areas (FGSV 390/1)
	M BGriff	Information Sheet on the Evaluation of Skid Resistance on Roads in the Wet (FGSV 401)
	MLuS	Information Sheet concerning Air Pollution on Roads with or without Peripheral Development (FGSV 336)
	M UVS	Information Sheet concerning Environmental Impact Assessments in Road Planning (FGSV 228)
	RABT	Guidelines for the Equipment and Operation of Road Tunnels (FGSV 339)
	RAL	Guidelines for the Design of Rural Roads (FGSV 201) (currently being drafted)
	RAS-Ew	Guidelines for the Design of Highways: Drainage with the RAS
	RAS-LP 2	Guidelines for the Design of Highways, Section 2: Landscape Management (FGSV 293/2)
	RAS-LP 1	Guidelines for the Design of Highways: Landscape Management: (RAS-LP), Section 1: Accompanying Plan for Landscaping and Environmental Protection (FGSV 293/1)
	RASt	Guidelines for the Design of Urban Roads (FGSV 200)
	RIN	Guidelines for Integrated Network Design (FGSV 121) (currently being drafted)
	RiStWag	Guidelines for Construction Measures on Roads in Water Protection Areas (FGSV 514)
	RLS	Guidelines for Noise Control on Roads (FGSV 334)
	RMS	Guidelines for Road Markings, Part 1: Dimensions and Geometrical Arrangement of Markings (FGSV 330/1)
	RPS	Guidelines for Passive Protective Devices on Roads using Vehicle Restraint Systems (FGSV 343)
	RSA	Guidelines for Securing Roadworks on Roads (FGSV 370)
	RVBA	Guidelines for Traffic Control Systems (currently being drafted)
	RWB	Guidelines for Directional Signing on Highways other than Motorways (FGSV 329)
	RWBA	Guidelines for Directional Signing on Motorways (FGSV 329/2)
	ZTV-Lsw	Additional Technical Terms of Contract and Guidelines for the Implementation of Noise Barriers on Roads (FGSV 258)
	ZTV M	Additional Technical Terms of Contract and Guidelines on Road Markings (FGSV 341)

Technical standards and specifications (cntd.)

VkBl[3]	AKS	Instructions for Calculating Costs in Road Construction
	PlafeR	Guidelines for Official Plan Approval in Accordance with the Federal Trunk Road Act (Plan Approval Guidelines)
	RE	Guidelines for the Drafting of Uniform Design Documents in Road Construction
	RiZ-ING	Standard Drawings for Engineering Works
	RiZaK	Standard Drawings for Noise Screens That Are Not Part of Civil Engineering Structures
	VLärmSchR	Guidelines for Road Traffic Noise Control on Federal Trunk Roads Constructed by the Federal Government
	WSchuZR	Guidelines for Game Fences on Federal Trunk Roads (Game Fence Guidelines)

The valid versions of the General Circulars concerning Road Construction (BMW ARS) can be downloaded from the website of the FGSV's publishing company (FGSV Verlag).

Sources:

1) **Beuth Verlag GmbH**
Address: Burggrafenstraße 6, 10787 Berlin, Germany
Tel.: +49 (0)30 2601-0, Fax: +49 (0)30 2601-1260
e-mail: info@beuth.de, Internet: www.beuth.de

2) **FGSV Verlag GmbH**
Address: Wesselinger Straße 17, 50999 Köln, Germany
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e-mail: info@fgsv-verlag.de, Internet: www.fgsv-verlag.de

3) **Verkehrsblatt-Verlag**
Address: Schleefstraße 14, 44287 Dortmund, Germany
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e-mail: info@verkehrsblatt.de, Internet: www.verkehrsblatt.de

All of the FGSV regulations listed above can also be obtained through the subscription service 'FGSV – Technisches Regelwerk – Digital'

Editorial advise:

Dear Expert,
please take notice, that the cited technical rules were principally only in german language available.

Appendix 10

List of illustrations and tables

List of illustrations

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List of abbreviations

Abbreviation	Meaning
A	exit type
AKS	Instructions for Calculating Costs in Road Construction
AM	motorway maintenance depot
AR	exit type for the connector road system
AR*	types for exits on connector roads
ARS	General Circular concerning Road Construction
ASR	adapted (‘compressed’) loop
ATR	adapted tangential slip road
AUSA	telephone network in authorities and premises
BAB	federal motorway
BAB-Fm	federal motorway telecommunications network
BImSchG	Federal Pollution and Noise Control Act
BImSchV	Regulation on the Implementation of the Federal Pollution and Control Act (Traffic Noise Ordinance)
BMVBS	Federal Ministry of Transport, Building, and Urban Development
BNatSchG	Federal Nature Conservation Act
DIN	Deutsches Institut für Normung (German Standardization Institute)
DTV	Average daily traffic volume (ADT)
E	entry type
E*	types for entries on mainline carriageways
EKA	motorway design classes
EKL	rural road design classes
EN	European standard
ER	entry type for the connector road system
FBR	edge of the carriageway
FFH	Fauna Flora Habitat
FStrAbG	Development of the Federal Trunk Road Network Act
FStrG	Federal Trunk Road Act
GSR	elongated loop
HOAI	Ordinance concerning Remuneration for Architects and Engineers
Kfz	motor vehicle
KV	small roundabouts
LBP	Accompanying Plan for Landscaping and Environmental Protection
Lkw	truck
LSA	traffic lights
LW	clear span
NLL	parallel left-turning lanes
PWC	unstaffed motorway services areas with or without toilet facilities
RLT	‘right-facing’ trumpet
ROG	Spatial Development Act
RQ	standard cross-section
StVO	German Road Traffic Regulations
StVZO	German Road Vehicle Regulations
SWIS	Road condition and weather information system
UVS	Environmental Impact Study
UVPG	Environmental Impact Assessment (EIA)
VBA	traffic control systems
VR-Typen	weaving areas for the connector road system
V-Typen	universally applicable weaving areas
VwV-StVO	General Administrative Provision on the German Road Traffic Regulations
WSG	water protection areas
ZP	object height

Remarks on the system of technical publications of the FGSV

R stands for regulations:

These publications either specify the technical design or realization (R1) or give recommendations on the technical design or realization (R2).

W stands for information documents:

These publications represent the current state-of-the-art knowledge and define how a technical issue shall be practicably dealt with or has already been successfully dealt with.

Category R1 indicates 1st category regulations:

R1-publications contain the contractual basis (Additional Technical Conditions of Contract and Guidelines, Technical Conditions of Delivery and Technical Test Specifications) as well as guidelines. They are always coordinated within the FGSV. R1-publications – in particular if agreed on as integral part of the contract – have a high binding force.

Category R2 indicates 2nd category regulations:

R2-publications contain information sheets and recommendations. They are always coordinated within the FGSV. Their application as state-of-the-art technology is recommended by the FGSV.

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W1-publications contain references. They are always coordinated within the FGSV but not with external parties. They represent current state-of-the-art knowledge within the respective responsible boards of the FGSV.

Category W2 indicates 2nd category documents of knowledge:

W2-publications contain working papers. These may include preliminary results, supplementary information and guidance. They are not coordinated within the FGSV and represent the conception of an individual board of the FGSV.

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