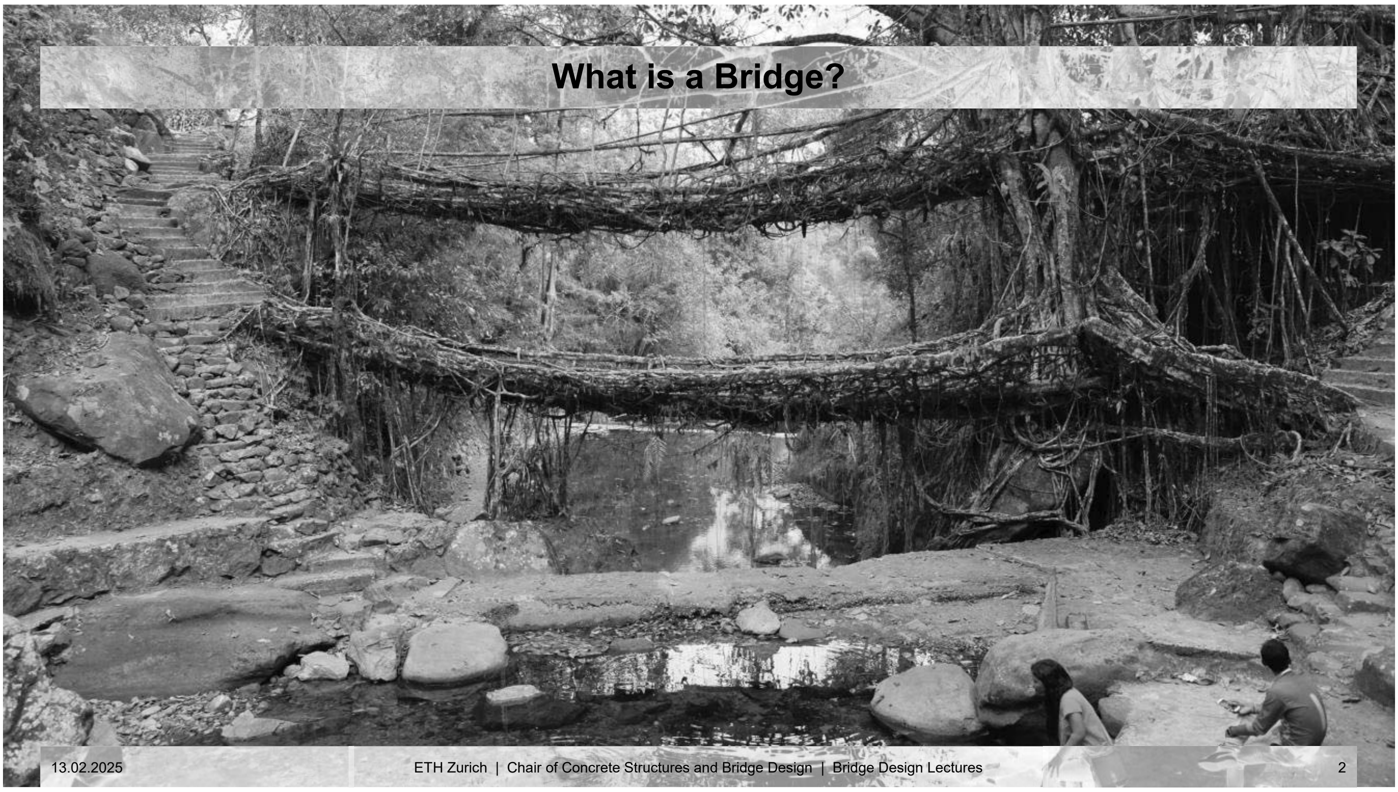
Bridge Design

Introduction



‘Living Root Bridges’, Meghalaya plateau, India

Photo Credit: Ferdinand Ludvig, professor for green technologies in landscape architecture at the Technical University of Munich; https://edition.cnn.com/style/article/living-bridges-india-scn/index.html

Akashi Kaikyō Bridge, Awaji Island and Kobe, Japan (1998)

Owner/Designer: Honshu-Shikoku Bridge Authority
Contractors: Obayashi Corp., Kawasaki Heavy Industries, Solétanche Bachy, Taisei Corp., Kawada Industries, Mitsubishi Heavy Industries Ltd., Yokogawa Bridge Corp., … (More than 100 contractors involved)

Type: Suspension
Materials: Steel (cables, pylons, deck truss), Reinforced Concrete (anchorages)
Longest main span in the world = 1,991 m
Overall length = 3,911 m
Pylon height = 283 m
Roadway bridge

References:
https://structurae.net/en/structures/akashi-kaikyo-bridge
https://www.fhwa.dot.gov/publications/publicroads/98julaug/worlds.cfm

Photo Credit: http://eskipaper.com/pic/getsecond

What is a Bridge?

Some definitions:

“a structure spanning and providing passage over a river, chasm, road, or the like.” [Dictionary.com]

“a structure carrying a pathway or roadway over a depression or obstacle (such as a river)” [Merriam-Webster]

“a structure that is built over a river, road, or railway to allow people and vehicles to cross from one side to the other” [Cambridge Dictionary]

“A bridge is a structure that is built over a railway, river, or road so that people or vehicles can cross from one side to the other.” [Collins Dictionary]

“A structure carrying a road, path, railway, etc. across a river, road, or other obstacle.” [Oxford Dictionary]

“a road, railway, or path that goes over a river, over another road etc, and the structure that supports it” [MacMillan Dictionary]

“A structure spanning and providing passage over a gap or barrier, such as a river or roadway.” [FARLEX]

None of them are complete but they define the basic characteristics of a bridge

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A bridge is a structure

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A bridge provides a passage for vehicles, people, water, materials, utilities, …

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A bridge crosses a natural or manmade obstacle.

Bridge Classification

Based on traffic carried:

- Road traffic
- Rail traffic
  (Heavy rail, Light rail)
- Non-motorised traffic
  (Pedestrians, Cyclists)
- Water
  (aqueducts, canals)
- Utilities
  (water, electricity, tele-communications, natural gas)
- Raw Material
  (conveyor bel
- Wildlife

Bridges may be classified based on their:

- Purpose/Function, i.e. the type of traffic that they carry
- Typology
- Construction Materials

Graphic Credit: http://blog.garverusa.com/2010/03/garver-awarded-multimodal-bridge.html

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- Raw Material
  (conveyor belts)
- Wildlife

Leonard P. Zakim Bunker Hill Memorial Bridge, Boston, MA, USA (2003)

Owner: Commonwealth of Massachusetts
Conceptual Design: Christian Menn (designer), Parsons Brinckerhoff
Detailed Design: Figg Bridge Engineers Inc., HNTB (Theodore Zoli)
Architect: Miguel Rosales
Erection Engineer: David Goodyear Engineering Services (now part of T.Y. Lin International)
Contractors: Atkinson Construction, Kiewit Corporation
Project Management: Bechtel Corporation, Parsons Brinckerhoff

Type: Cable-Stayed
Materials: Steel-concrete composite (main span), Prestressed concrete (side spans)
Main span = 227 m
Overall length = 436 m
Pylon height = 98 m
Roadway bridge

References:
https://structurae.net/en/structures/leonard-p-zakim-bunker-hill-memorial-bridge

Photo Credit: https://www.amazon.com/Boston-MA-Leonard-night-Highsmith/dp/B01LVZCX4J

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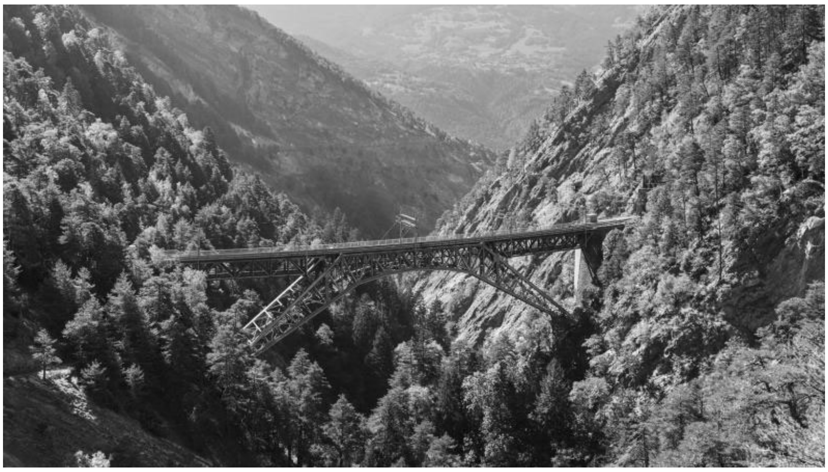

Bietschtal Bridge, Raron, Valais, Switzerland (1913) – Retrofitted in 1986

Owner: BLS Bern-Lötschberg-Simplon-Bahn
Design & Construction: Albert Buss & Cie, Pratteln

Type: Arch Truss
Materials: Steel
Arch span = 95 m
Overall length = 110 m
Railway bridge

References:
https://structurae.net/en/structures/bietschtalbrucke
SBB & GSK, "Schweizer Bahnbrücken," Verlag Scheidegger & Spiess, Zürich (2013)

Photo Credit: Georg Aerni (2012)

Note:

Railway traffic can also be classified by the track system, such as standard gauge ("Normalspur", 1.435 m) and narrow gauge ("Meterspur", 1.00 m) in Switzerland. Light rail systems include tramways, which usually use narrow gauge tracks. While standard track traffic loads are well standardised through UIC, traffic loads on light rail systems vary strongly and are often specified by the owner.

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- Raw Material
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- Wildlife

Tilikum Crossing, Portland, OR, USA (2015)

Owner: TriMet
Conceptual Design: HNTB
Detailed Design: T.Y. Lin International
Architect: Donald MacDonald Architects
Contractor: Kiewit Infrastructure West Co.

Type: Cable-Stayed – Extradosed Hybrid
Materials: Concrete
Main span = 240 m
Overall length = 520 m
Pylon height = 55 m
Transit bridge (Light rail, streetcars, buses, bicycles, pedestrians, emergency vehicles)

References:
https://structurae.net/en/structures/tilikum-crossing
https://en.wikipedia.org/wiki/Tilikum_Crossing
https://www.tylin.com/en/projects/tilikum_crossing_bridge_of_the_people

(Photo Credits: Tom Paiva Photography, Blueprint22 Photography)

Bridge Classification

Based on traffic carried:

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- Raw Material
  (conveyor belts)
- Wildlife

Max-Eyth Footbridge, Stuttgart, Germany (1989)

Owner: Landeshauptstadt Stuttgart
Designer: Schlaich Bergermann Partner
Architect: Schlaich Bergermann Partner, Brigitte Schlaich-Peterhans
Contractors: Pfeifer Seil- und Hebetechnik GmbH, Wayss & Freytag

Type: Suspension
Materials: Steel
Main span = 114 m
Overall length = 164 m
Pylon height = 24.5 m
Pedestrian bridge

References:
https://structurae.net/en/structures/max-eyth-footbridge
https://www.sbp.de/projekt/fussgaengerbruecke-max-eyth-see-ueber-den-neckar/ (Photo Credit)

Bridge Classification

Based on traffic carried:

- Road traffic
- Rail traffic
  (Heavy rail, Light rail)
- Non-motorised traffic
  (Pedestrians, Cyclists)
- Water
  (aqueducts, canals)
- Utilities
  (water, electricity, tele-communications, natural gas)
- Raw Material
  (conveyor belts)
- Wildlife

Cykelslangen (Bicycle Snake), Copenhagen, Denmark (2014)

Owner: Københavns Kommune
Designer: Rambøll
Architect: Dissing+Weitling
Contractors: MT Højgaard

Type: Girder
Materials: Steel
Typical span = 17 m
Overall length = 230 m
Deck width = 4.6 m
Cyclist bridge

References:
https://structurae.net/en/structures/cykelslangen

Photo Credit: https://www.toposmagazine.com/copenhagen-cykelslangen/#Rasmus-Hjortshoj-Cykelslangen-LARGE-07-631x440

Bridge Classification

Based on traffic carried:

- Road traffic
- Rail traffic
  (Heavy rail, Light rail)
- Non-motorised traffic
  (Pedestrians, Cyclists)
- Water
  (aqueducts, canals)
- Utilities
  (water, electricity, tele-communications, natural gas)
- Raw Material
  (conveyor belts)
- Wildlife

Alloz Aqueduct (Acueducto sobre el río Salado), Valle de Yerri/Deierri, Navarra, Spain (1939)

Designer: Eduardo Torroja
Contractors: Huerta y Cía., S.A.

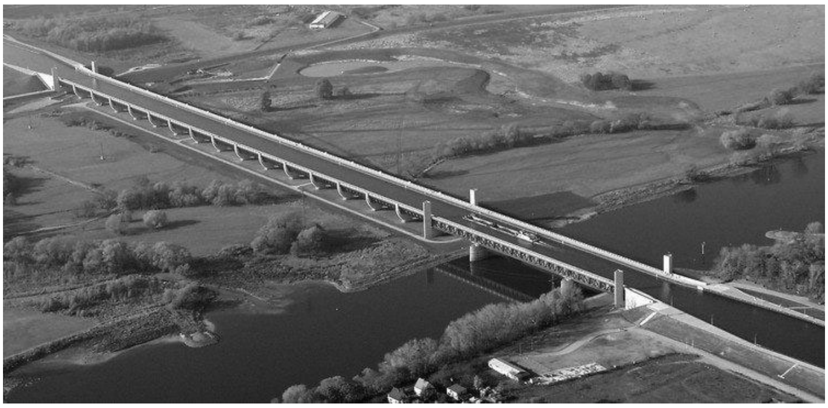
Type: Girder
Materials: Prestressed Concrete (superstructure), Reinforced Concrete (substructure)
Typical span = 20 m
Overall length = 219 m
Aqueduct bridge

References:
https://structurae.net/en/structures/alloz-aqueduct

Bridge Classification

Based on traffic carried:

- Road traffic
- Rail traffic
  (Heavy rail, Light rail)
- Non-motorised traffic
  (Pedestrians, Cyclists)
- Water
  (aqueducts, canals)
- Utilities
  (water, electricity, tele-communications, natural gas)
- Raw Material
  (conveyor belts)
- Wildlife



Magdeburg Canal Bridge, Hohenwarthe, Möser, Jerichower Land, Saxony-Anhalt, Germany (2003)

Owner: Bundesministerium für Verkehr, Bau- und Wohnungswesen
Conceptual Design: Ingenieurbüro Grassl GmbH Beratende Ingenieure Bauwesen
Detailed Design: HRA Ingenieurgesellschaft mbH Bochum
Architect: Winking · Froh Architekten BDA
Contractors: Bilfinger Berger SE, Dillinger Stahlbau GmbH, OSB Oderberger Stahlbau GmbH

Type: Truss (main crossing) / Girder (approach viaduct)
Materials: Steel (superstructure), Reinforced Concrete (substructure)
Main span = 106 m
Typical approach span = 43 m
Overall length = 918 m
Canal bridge

References:
https://structurae.net/en/structures/magdeburg-canal-bridge

Photo Credit: https://info-maniac.com/en/Attraction/magdeburg-water-bridge/

Bridge Classification

Based on traffic carried:

- Road traffic
- Rail traffic
  (Heavy rail, Light rail)
- Non-motorised traffic
  (Pedestrians, Cyclists)
- Water
  (aqueducts, canals)
- Utilities
  (water, electricity, tele-communications, natural gas)
- Raw Material
  (conveyor belts)
- Wildlife

Danube Pipeline Bridge near Vienna, Vienna 11 / Mannwörth, Austria

Contractor: Waagner-Biro AG

Type: Suspension
Materials: Steel
Main span = 260 m
Pipeline bridge

References:
https://structurae.net/en/structures/danube-pipeline-bridge-near-Vienna (Photo Credit)

Bridge Classification

Based on traffic carried:

- Road traffic
- Rail traffic
  (Heavy rail, Light rail)
- Non-motorised traffic
  (Pedestrians, Cyclists)
- Water
  (aqueducts, canals)
- Utilities
  (water, electricity, tele-communications, natural gas)
- Raw Material
  (conveyor belts)
- Wildlife

Flyingbelt system at Holcim Barosso Cement Manufacturing Plant, Brazil (2015)

Client: LafargeHolcim
Design & Construction: Semperit Group (conveyor belt), Agudio (ropeway)

Type: Ropeway
Materials: Steel
Overall length = 7,200 m
Conveyor belt bridge

References:
https://www.agudio.com/en/products/flyingbelt/main-projects/barroso-brazil
https://mqworld.com/2016/07/04/semperit-group-innovative-aerial-conveyor-system-flyingbelt-sempertrans-agudio-put-operation-brazil/ (Photo Credit)

Bridge Classification

Based on traffic carried:

- Road traffic
- Rail traffic
  (Heavy rail, Light rail)
- Non-motorised traffic
  (Pedestrians, Cyclists)
- Water
  (aqueducts, canals)
- Utilities
  (water, electricity, tele-communications, natural gas)
- Raw Material
  (conveyor belts)
- Wildlife

I-80 Wildlife Overpass, Park City, Utah, USA (2018)

Client: Utah Department of Transportation
Design: WSP

Type: Girder
Materials: Steel-concrete composite
Overall length = 98 m

References:
https://www.atlasobscura.com/places/i-80-wildlife-overpass (Photo Credit)
https://www.wsp.com/en-CH/insights/utah-opens-states-first-wildlife-bridge-overpass

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Great Seto Bridge, Seto Inland Sea, Honshu & Shikoku, Japan (1988)

Series of six double-deck bridges connecting the Okayama and Kagawa prefectures across a series of five islands.

Owner: Honshu Shikoku Bridge Authority

Overall length = 13 km
Types: Suspension, Cable-Stayed, Truss

References:
https://en.wikipedia.org/wiki/Great_Seto_Bridge
https://www.ana-cooljapan.com/destinations/kagawa/greatsetobridge (Photo Credit)

Bridge Classification

Based on typology:

- Slab (Plattenbrücke)
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

I-70 Overpass at East Street, Junction City, KS, USA

Owner: Kansas Department of Transportation
Designer: BG Consultants

Type: Slab (haunched)
Materials: Prestressed Concrete (superstructure), Reinforced Concrete (substructure)
Roadway bridge

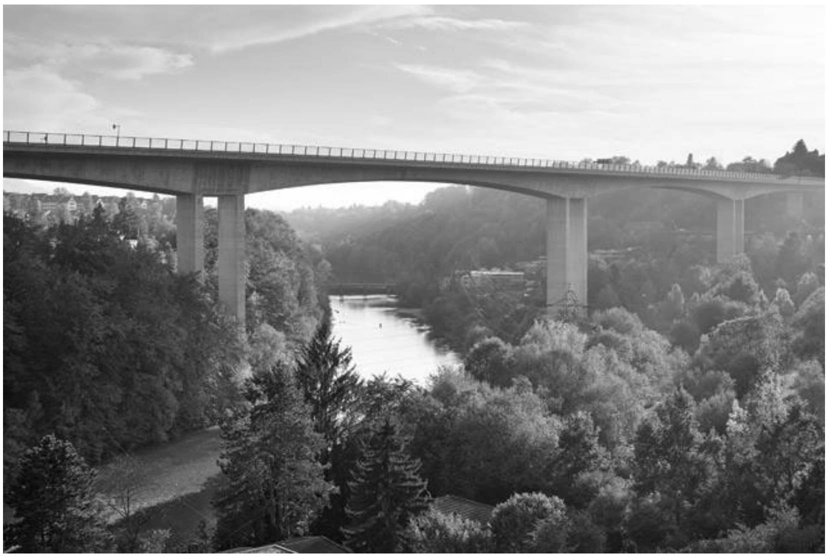
References:

http://www.bgcons.com/project/post-tensioned-rcsh-bridge-on-i-70-overpass-at-east-street (Photo Credit)

Bridge Classification

Based on typology:

- Slab
- Girder (Balkenbrücke)
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems



Felsenau Viaduct, Bern, Switzerland (1974)

Design: Christian Menn, Rigendinger (W. Maag), Emch+Berger AG

Type: Girder
Materials: Prestressed Concrete (superstructure), Reinforced Concrete (substructure)
Longest span = 144 m
Overall length = 1,116 m
Roadway bridge

References:

https://structurae.net/en/structures/felsenau-viaduct

https://jadetheobscure.files.wordpress.com/2016/02/menn-bruecken-p190-felsenau-bern-1972.jpg (Photo Credit)

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss (Fachwerkbrücke)
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Firth of Forth Bridge, Queensferry, Edinburgh, UK (1890)

Designer: Sir John Fowler, Benjamin Baker
Contractor: Sir William Arrol & Co.

Type: Cantilever Truss
Materials: Steel
Main span(s) = (2x) 521 m
Overall length = 2,523 m
Railway bridge

References:
https://structurae.net/en/structures/forth-rail-bridge
https://www.nms.ac.uk/explore-our-collections/stories/science-and-technology/forth-bridge-paint-mixer/

Photo Credit: Ross G. Strachan

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame (Rahmenbrücke)
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Wildüberführung Halbmil, Chur, Switzerland (2016)

Owner: Bundesamt für Strassen Astra
Designer: dsp Ingenieure+Planer AG
Architect: Eduard Imhof

Type: Frame
Materials: Prestressed Concrete
Overall length = 54 m (two spans crossing A13 motorway, RhB and SBB lines, cover width 50 m)
Wildlife crossing (with rural road)

Photo Credit: Beat Bühler Fotografie Zürich

Note:

The term “frame bridge” is used here for bridges where the abutment walls provide significant clamping (hogging moments) to the bridge girder, which is in most cases a slab. Frame action does also exist in many other bridge typologies, such as girder bridges with monolithically connected piers.

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Strut frame (Sprengwerk)
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Mühlebach Bridge, Stalden & Törbel, VS, Switzerland (1959)

Owner: Visp-Zermatt-Bahn
Designer: Alexandre Sarrasin

Type: Strut Frame
Materials: Concrete
Overall length = 67 m
Railway bridge

References:
SBB & GSK, “Schweizer Bahnbrücken,” Verlag Scheidegger & Spiess, Zürich (2013)

Photo Credit: Georg Aerni (2012)

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch (Bogenbrücke)
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Tamina Bridge, Pfäfers, St. Gallen, Switzerland (2017)

Owner: Tiefbauamt St. Gallen
Design: Leonhardt, Andrä und Partner
(with dsp Ingenieure + Planer AG as project partner)
Contractors: J. Erni AG, Meisterbau AG, STRABAG AG

Type: Arch
Materials: Reinforced Concrete (Arch), Prestressed Concrete (Deck)
Arch span = 259 m
Overall length = 475 m
Roadway bridge

References:
https://structurae.net/en/structures/tamina-bridge

Photo Credit: Von Kecko from Rural area of Eastern Switzerland - Tamina Bridge Pfäfers-Valens, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=80847098

Bridge Classification

Based on typology:
- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension (Hängebrücke)
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Golden Gate Bridge, San Francisco, CA, USA (1937)

Designers: Joseph Strauss, Leon Moisseiff, Charles Alton Ellis
Architect: Irving Morrow
Contractor: Bethlehem Steel Co.

Type: Suspension
Materials: Steel
Main span = 1,280 m
Overall length = 2,737 m
Tower height = 227 m
Roadway bridge

References:
https://structurae.net/en/structures/golden-gate-bridge
https://en.wikipedia.org/wiki/Golden_Gate_Bridge#Construction

https://www.ge.com/reports/engineers-build-golden-gate-bridge-today/ (Photo Credit)

Bridge Classification

Based on typology:
- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed (Schrägseilbrücke)
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Lali Bridge, Khuzestan, Iran (2011)

Owner: Water & Power Resources Development Co.
Tender Designer: Hexa engineering
Contractor: Boland Payeh Construction Co., with NCK and dsp Ingenieure+Planer AG as consultants)

Type: Cable-Stayed
Materials: Concrete
Main span = 256 m
Overall length = 460 m
Pylon height = 145 m
Roadway bridge

References:
https://structurae.net/en/structures/lali-bridge
http://www.dsp.ch/tl_files/dsp/dienstleistungen/01_brueckenbau_neubau/21_30_Lali_Bridge_Iran.pdf

Boland Payeh Construction Co., Dr. Ali Najafi (Photo Credit)

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- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

clear distinction?
(see notes)

Sunniberg Bridge, Klosters-Serneus, Grisons, Switzerland (2005)

Owner: Canton of Graubünden
Designer: Christian Menn
Architect: Andrea Deplazes
Contractors: Batigroup AG, Vetsch AG

Type: Extradosed (Cable-Stayed according to Ch. Menn, who never accepted the term “extradosed”)
Materials: Prestressed Concrete (superstructure), Reinforced Concrete (substructure)
Longest span = 140 m
Overall length = 526 m
Pylon height = 77 m
Roadway bridge

References: https://structurae.net/en/structures/sunniberg-bridge

Note: Basically, “extradosed bridges” can be interpreted as cable stayed bridges with very flat inclinations of the stay cables, such that normal forces in the girder dominate over the vertical support provided by the cables – which usually also requires a stiffer girder than in cable stayed bridges. They could however also be seen as externally prestressed bridges with cables lying partially outside the depth of the cross-section.

A possible criterion for the classification is the design criterion used for the cables: Either they are designed and detailed as stay cables (strict fatigue stress limitations, expensive technology, but less restrictive partial factors on permanent loads vs. prestress) or as external post-tensioning cables (higher stresses in cables permitted, inexpensive technology). In fact, the first “extradosed” bridges used the less expensive external prestressing technology, which economically at least partly compensates the structural inefficiency caused by the flat inclination of the cables. However, external prestressing technology is inadequate for extradosed cables (waterproofing, fatigue, dynamic effects), and recent extradosed bridges therefore use technology closer to stay cables. For more details, see IABSE SED Nr. 19, 2019.

Following the criteria above, the Sunnibergbrücke is indeed rather a cable-stayed bridge: stay cable

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung (Unterspannter Träger)
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Baltschieder Viaduct, Baltschieder & Eggerberg, VS, Switzerland (1988)

Owner: Bern-Lötschberg-Simplon-Bahn
Design: Emch + Berger, BLS Bauabteilung
Construction: Ed. Züblin & Cie, VSE International AG

Type: Underslung Girder
Materials: Concrete
Main span = 50 m
Overall length = 103 m
Railway bridge

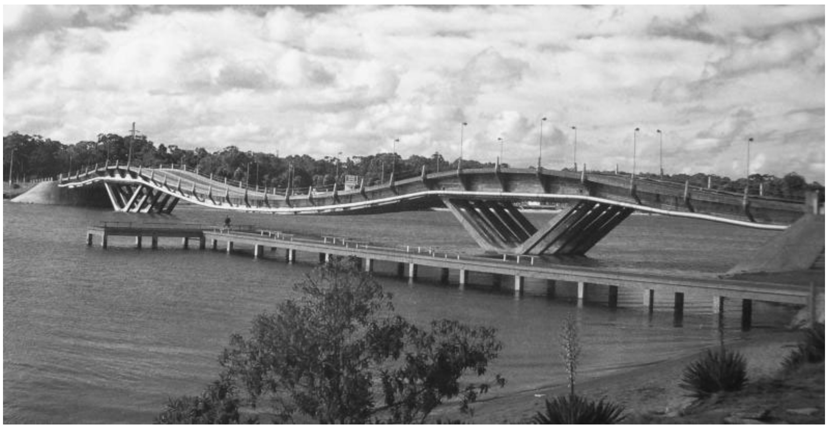
References:
https://structurae.net/en/structures/baltschiederbrucke
SBB & GSK, “Schweizer Bahnbrücken,” Verlag Scheidegger & Spiess, Zürich (2013)

Photo Credit: Georg Aerni (2012)

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon (Spannbandbrücke)
- Floating
- Movable
- Hybrid systems



Lionel Viera Bridge (Puente del Este-La Barra), Maldonado River, Uruguay (1965)

Design: Lionel Viera

Type: Stress Ribbon
Materials: Prestressed Concrete
Main span = 90 m
Overall length = 150 m
Roadway bridge

References:
https://structurae.net/en/structures/puente-leonel-viera
https://en.wikipedia.org/wiki/Leonel_Viera_Bridge (Photo Credit)

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating (Schwimmbrücke)
- Movable
- Hybrid systems

SR 520 Evergreen Point Floating Bridge, Seattle, WA, USA (2016)

Owner: Washington State Department of Transportation (WSDOT)
Design: WSDOT
Construction: Kiewit-General-Manson JV

Type: Floating/Pontoon
Materials: Concrete
Overall length = 2,350 m
Roadway bridge

References:
https://en.wikipedia.org/wiki/Evergreen_Point_Floating_Bridge
https://structurae.net/en/structures/evergreen-point-floating-bridge
https://www.wsdot.wa.gov/sites/default/files/2017/05/16/SR520-Booklet-FB042017.pdf
https://www.enr.com/blogs/15-evergreen/post/42615-more-milestones-hit-in-sr-520-floating-bridge-construction (Photo Credit)

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable (Klappbrücke, …)
- Hybrid systems

La Porta d'Europa Bridge, Barcelona, Spain (2000)

Owner: Autoritat Portuària de Barcelona
Design: Arenas & Asociados Ingeniería de Diseño
Construction: FCC Fomento de Construcciones y Contratas, Guinovart, Urssa

Type: Bascule
Materials: Steel
Longest span = 54 m
Overall length = 242 m
Roadway bridge

References:
https://structurae.net/en/structures/la-porta-d-europa-bridge
http://www.arenasing.com/en/projects/movable-bridges/porta-deuropa-bridge-Barcelona (Photo Credit)

Bridge Classification

Based on typology:

- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Yavuz Sultan Selim (Third Bosporus) Bridge, Istanbul, Turkey (2016)

Owner: Republic of Turkey
Design: Michel Virlogeux, T ingénierie, Genève
Construction: Hyundai Engineering & Construction, SK Engineering & Construction

Type: Suspension with stay cables
Materials: Steel (superstructure), Reinforced Concrete (substructure)
Main span = 1,408 m
Overall length = 1,875 m
Roadway & Railway bridge

References:
https://structurae.net/en/structures/yavuz-sultan-selim-bridge
https://www.enr.com/articles/40438-record-turkey-bridge-sets-the-pace-for-its-innovators-new-ceo (Photo Credit)

Bridge Classification

Based on typology:
- Slab
- Girder
- Truss
- Frame
- Strut frame
- Arch
- Suspension
- Cable-Stayed
- Extradosed
- Underslung
- Stress-ribbon
- Floating
- Movable
- Hybrid systems

Miho Museum Bridge, Kyoto, Japan (1997)

Owner: Shumei Culture Foundation
Designers: Aoki Corporation, Leslie E. Robertson & Associates, R.L.L.P., Nakata & Associates, Whole Force Studio
Contractors: Shimizu Corporation, Kawasaki Heavy Industries, Sumitomo Construction

Type: Cable-stayed/Underslung
Materials: Steel
Span = 120 m
Pedestrian bridge

References:
https://structurae.net/en/structures/miho-museum-footbridge
https://www.lera.com/miho-museum-and-bridge-c63q (Photo Credit)

Bridge Classification

Based on material:
- Masonry
- Timber
- Iron
- Steel
- Concrete
- Composite
  (steel-concrete)

Tower Bridge, London, UK (1894)

Designers: Henry Marc Brunel, John Wolfe-Barry
Architect: Sir Horace Jones
Contractor: Sir William Arrol

Type: Bascule
Materials: Steel, Masonry veneer
Main span = 79 m
Overall length = 286 m
Roadway/Pedestrian bridge

References:
https://structurae.net/en/structures/tower-bridge
https://fr.wikipedia.org/wiki/Tower_Bridge#/media/Fichier:Tower_Bridge_at_dawn_24-01-2015.jpg (Photo Credit)

Bridge Classification

Based on material:
- Masonry
- Timber
- Iron
- Steel
- Concrete
- Composite
  (steel-concrete)

Landwasser Viaduct, Filisur, Grisons, Switzerland (1902)

Designers: Friedrich C. S. von Hennings, Alexander Acatos, Robert Moser
Contractor: Müller & Zeerleder

Type: Arch Viaduct
Materials: Masonry
Typical span = 20 m
Overall length = 100 m
Railway bridge

References:
https://structurae.net/en/structures/landwasser-viaduct
https://www.mystsnet.com/en/stories/9-instagrammable-spots-along-the-grand-train-tour/#next (Photo Credit)

Bridge Classification

Based on material:

- Masonry
- Timber
- Iron
- Steel
- Concrete
- Composite
  (steel-concrete)

Agger Bridge, Lohmar Höngersberg, Germany (2014)

Owner: City of Lohmar
Designer: Schaffitzel Holzindustrie GmbH + Co.
Contractor: Ingenieurbüro Miebach

Type: Tied-Arch
Materials: Timber
Main span = 45 m
Overall length = 65 m
Roadway bridge

References:
https://www.schaffitzel.de/en/bridge-construction/references/289-hoengesberg-de
https://www.ib-miebach.de/en/projects/timber-bridges/ (Photo Credit)

Bridge Classification

Based on material:
- Masonry
- Timber
- Iron
- Steel
- Concrete
- Composite
  (steel-concrete)

Iron Bridge, Coalbrookdale, UK (1779)

Owner: Telford and Wrekin Borough Council
Designer: Abraham Darby III
Architect: Thomas Farnolls Pritchard

Type: Arch
Materials: Cast Iron
Main span = 30 m
Overall length = 60 m
Roadway bridge (until 1934), Pedestrian bridge

References:
https://structurae.net/en/structures/iron-bridge
https://www.flickr.com/photos/45777493@N06/4394579596/ (Photo Credit)

Bridge Classification

Based on material:
- Masonry
- Timber
- Iron
- Steel
- Concrete
- Composite
  (steel-concrete)

Eglisau Bridge, Eglisau, Zurich, Switzerland (1897)

Owner: Schweizerische Nordostbahn, SBB
Designer: Schweizerische Nordostbahn, Robert Moser & Züblin Ingenieure, Adolf Bühler
Contractor: Albert Buss & Cie, Gutehoffnungshütte

Type: Truss
Materials: Steel
Main span = 90 m
Overall length = 439 m
Railway bridge

References:
https://structurae.net/en/structures/eglisau-railroad-bridge
SBB & GSK, “Schweizer Bahnbrücken,” Verlag Scheidegger & Spiess, Zürich (2013)

Photo Credit: Jesus Portas (https://trainspo.com/photo/82776/?list=all)

Bridge Classification

Based on material:
- Masonry
- Timber
- Iron
- Steel
- Concrete
- Composite
  (steel-concrete)

Vulpera/Tarasp Bridge, Tarasp, Grisons, Switzerland (2010)

Owner: Tiefbauamt Graubünden

Designer: dsp Ingenieure & Planer AG, ACS Partner AG
Architect: Eduard Imhof
Type: Girder
Materials: Prestressed Concrete (superstructure), Reinforced Concrete (substructure)
Main span = 104 m
Overall length = 236 m
Roadway bridge

References:
https://structurae.net/en/structures/vulperatarasp-bridge

Photo Credit: dsp Ingenieure & Planer AG

Bridge Classification

Based on material:

- Masonry
- Timber
- Iron
- Steel
- Concrete
- Composite
  (usually steel-concrete)

Schönenwerd Bridge, Dietikon, Switzerland (2017)

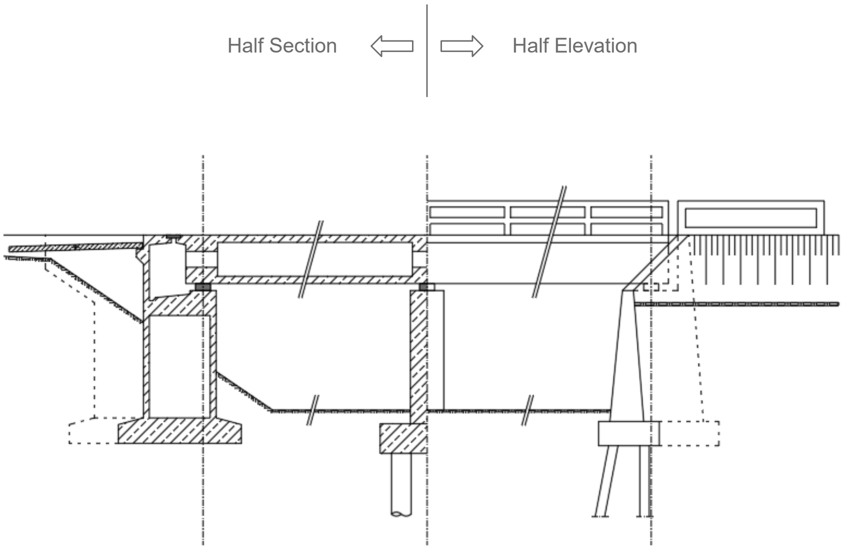
Owner: Tiefbauamt Kanton Zürich
Designer: dsp Ingenieure & Planer AG
Architect: Balz Amrein

Type: Girder
Materials: Steel-Concrete composite
Span = 50 m
Roadway bridge

References:
http://www.dsp.ch/bruecken-neubau.html

Photo Credit: dsp Ingenieure & Planer AG

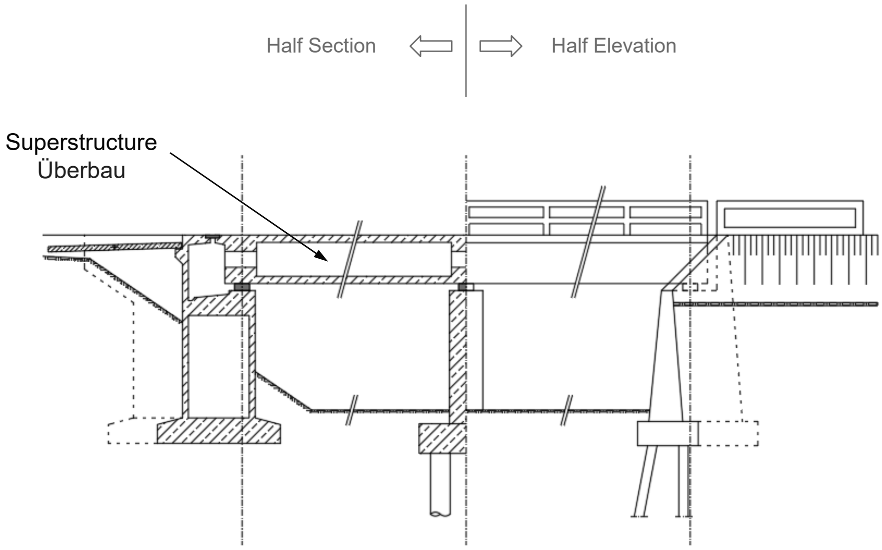
General Characteristics - Nomenclature



Notes:

For the purposes of defining the general characteristics of bridges, an example of a typical roadway girder bridge is considered.

General Characteristics - Nomenclature



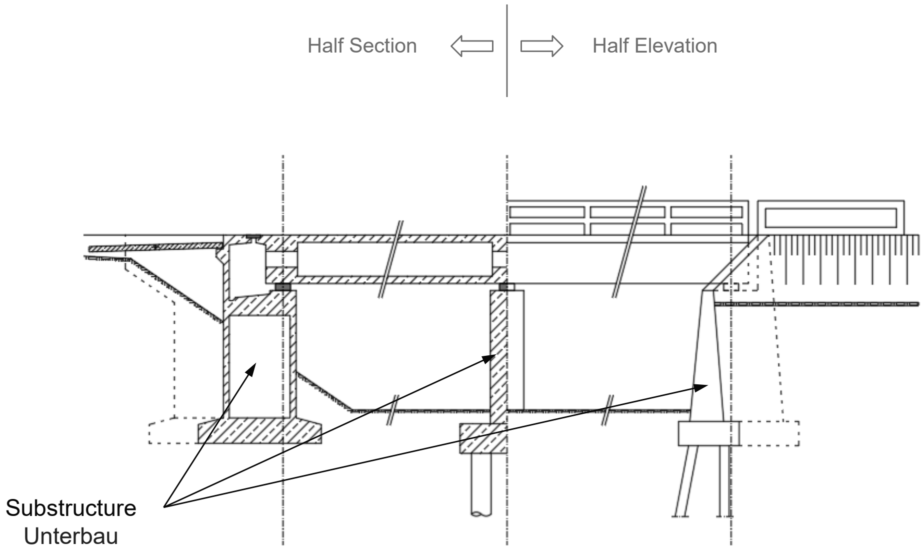
Notes:

In bridges, two main parts are usually distinguished: The superstructure and the substructure.

The superstructure includes the main load bearing structural elements along with the roadway (or railway, etc., depending on the type of traffic carried). It includes all of the elements that facilitate the transport of vehicles, people, material, etc, such as: wearing surface, sealing membrane, sidewalks, traffic barriers and pedestrian railings, drainage systems, utility ducts, etc. It also includes elements to accommodate for expansion and contraction of the superstructure and its support onto the substructure. Examples are presented in the following slides.

[continued on following slide]

General Characteristics - Nomenclature

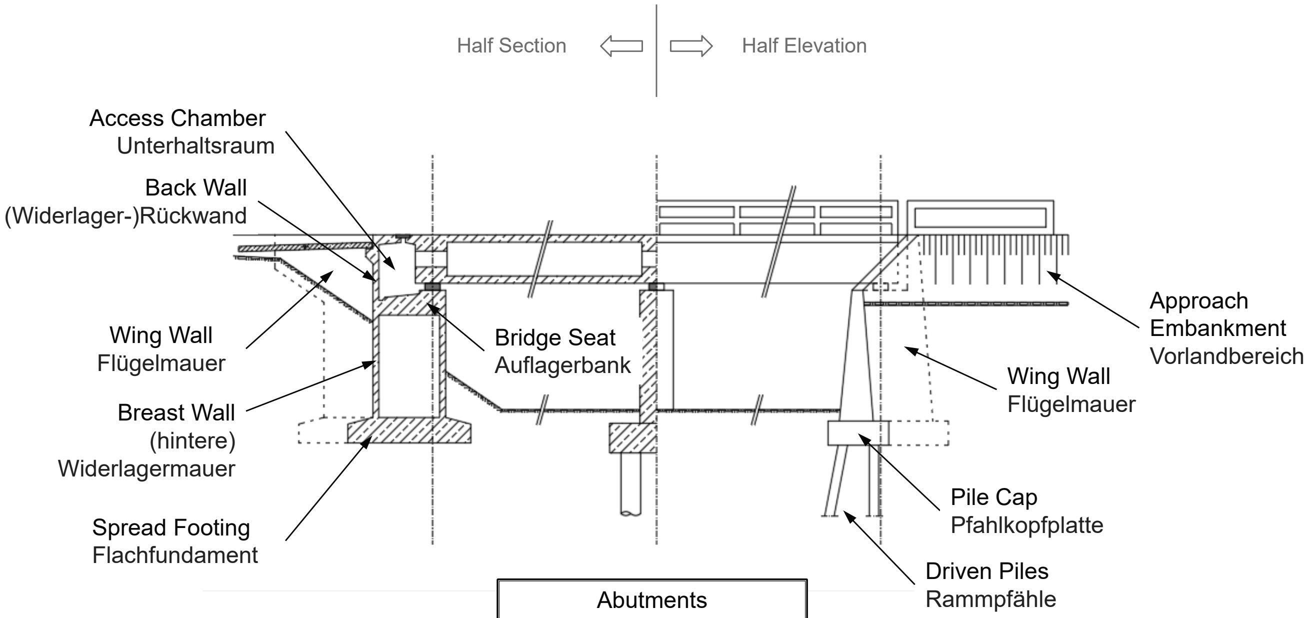


Notes [continued from previous slide]:

The substructure includes the piers (abutments, intermediate), foundations, retaining walls, approach works (such as embankments) to allow for transitioning from the road to the bridge, works to protect the foundations against scour or the piers from vehicle/vessel collision, etc.

The distinction between superstructure and substructure elements is relatively straightforward for structural systems such as girder bridges, as illustrated in this example. For other structural systems, such as arches (especially) or cable-supported bridges, this distinction may not always be as apparent. We will examine these structural systems in detail at the corresponding lectures.

General Characteristics - Nomenclature



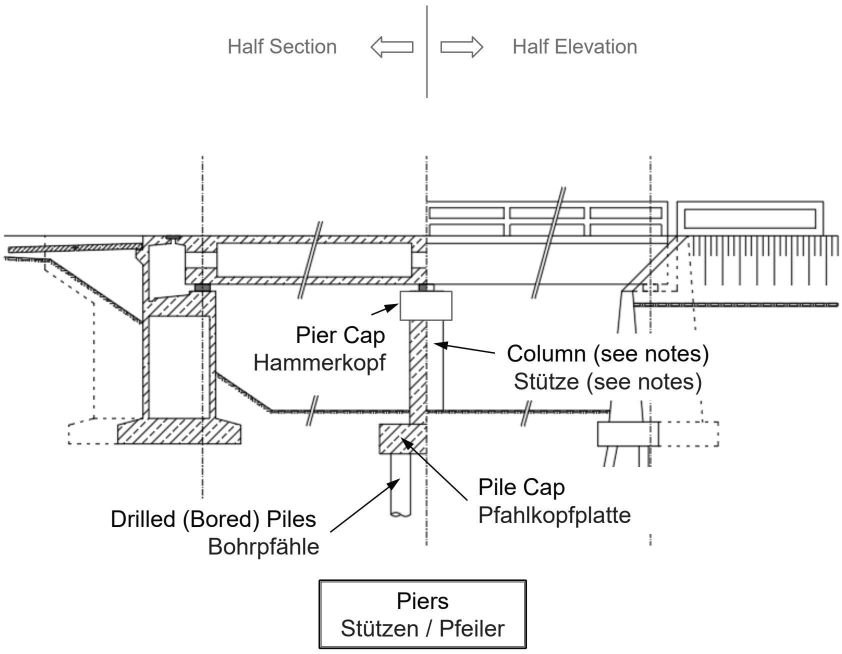
Abutments
Widerlager / Brückenende

Notes:

The wing walls retain the approach embankment at the ends of the bridge. They can either be fixed to the abutments or independent substructure elements.

It is desirable to detail the abutments so that they include an access chamber to facilitate inspection and maintenance operations.

General Characteristics - Nomenclature

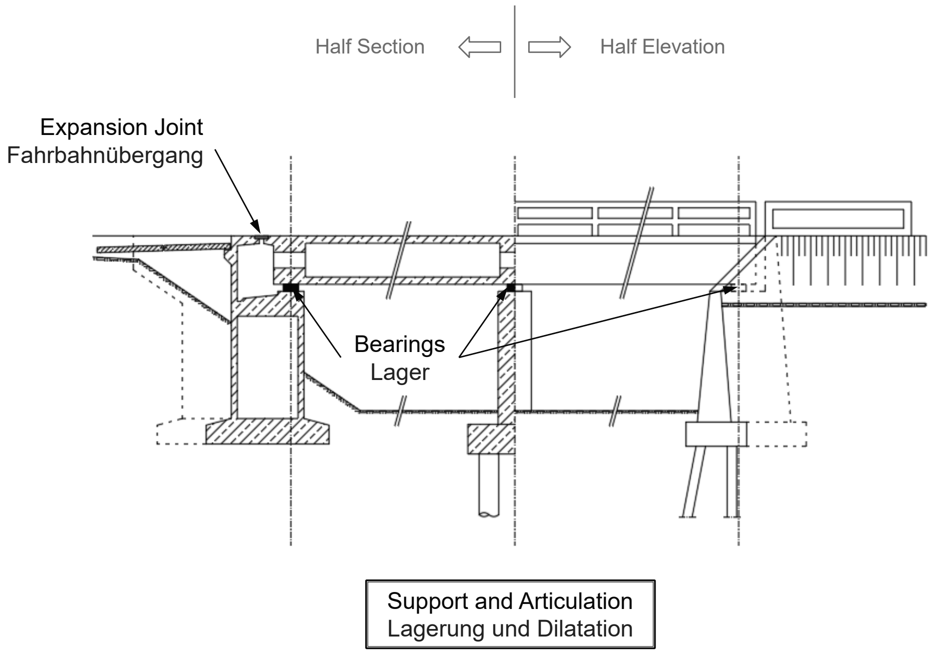


Notes:

The term “column” is specifically used for the vertical elements supporting the “pier cap” in bridges with a superstructure consisting of several girders (precast concrete I-beams or steel girders), which are in turn supported by the pier cap.

In other bridges, the term “column” is uncommon (“Stütze/Pfeiler” = “pier”).

General Characteristics - Nomenclature

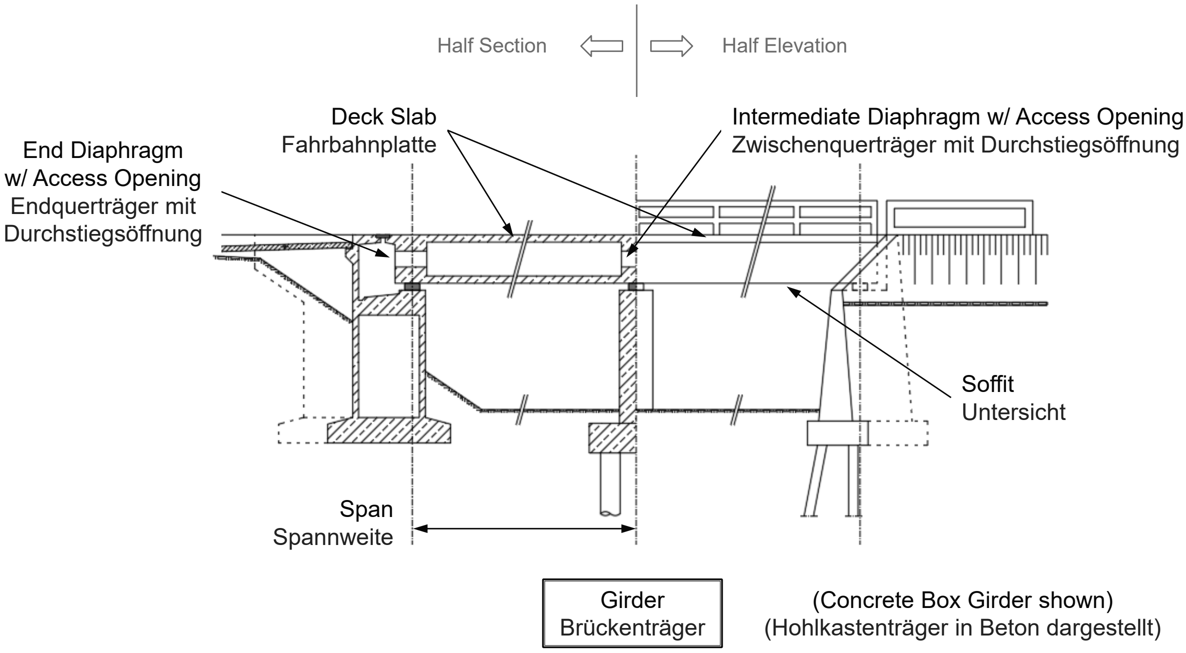


Notes:

Bearings are devices inserted between the superstructure and the substructure, that transmit the superstructure loads to the substructure, while also allowing for relative movements between superstructure and substructure (displacements and/or rotations).

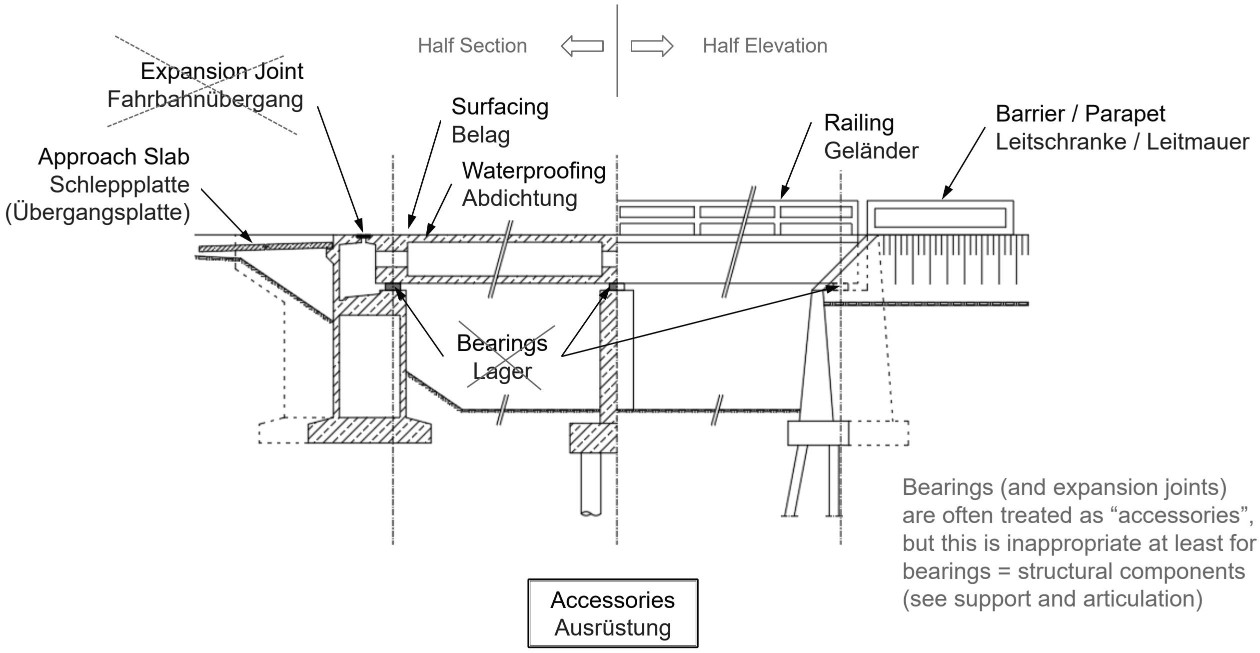
Expansion joints accommodate movements of the girder ends while facilitating a smooth ride (see next slide for more information).

General Characteristics - Nomenclature



(Concrete Box Girder shown)
(Hohlkastenträger in Beton dargestellt)

General Characteristics - Nomenclature



Notes:

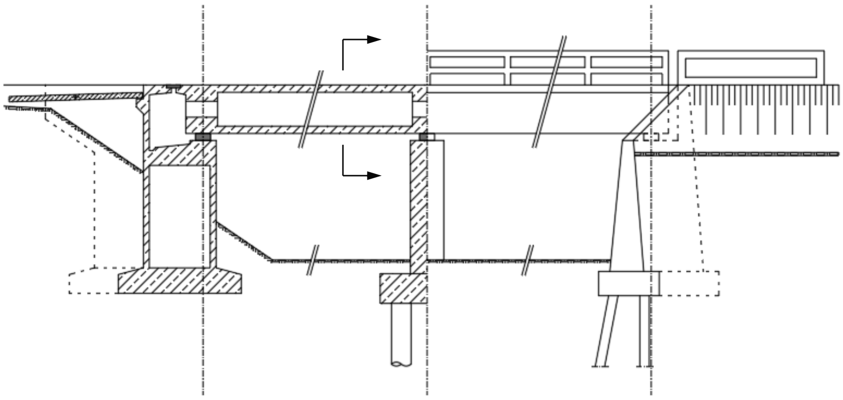
In order to ensure a smooth transition between the road (approach embankment) and the bridge, approach slabs are installed next to the abutments. Their function is to ensure a more gradual transition between the relatively soft embankment and the relatively rigid bridge, thus avoiding a kink in the roadway surface due to differential settlements.

Relative movements between the superstructure and substructure elements or among adjacent superstructure segments in the case of a discontinuous superstructure, are accommodated at joint locations through special devices (expansion joints). The type and complexity of these devices depends on the type of use of the bridge and the magnitude of the movements that have to be accommodated. The movements can be produced by a combination of concrete shrinkage and creep, post-tensioning shortening, thermal variations, dead and live loads, wind and seismic loads, and imposed settlements.

The durability and maintenance issues, commonly encountered with expansion joints, can be avoided through structural systems that feature continuous spans (over intermediate piers) built integrally with the abutments, thus eliminating expansion joints. he degree of continuity achieved varies depending on the connection details between the superstructure, substructure and approach slab elements. Elimination of expansion joints however results in the development of secondary stresses in the superstructure and substructure elements due to the imposed restraints on the superstructure movements. Therefore, there is a practical span limit beyond which joints must be introduced to control the magnitude of the secondary stresses. For more details, see the chapter on support and articulation.

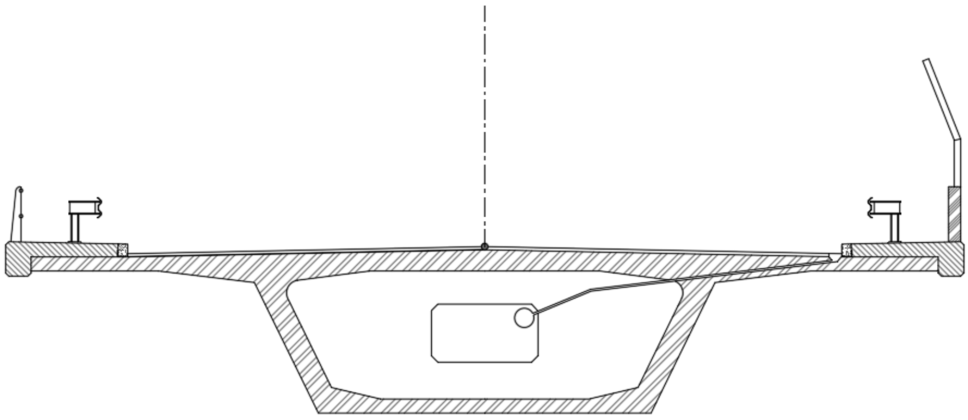
General Characteristics - Nomenclature

Half Section ⇦ ⇨ Half Elevation



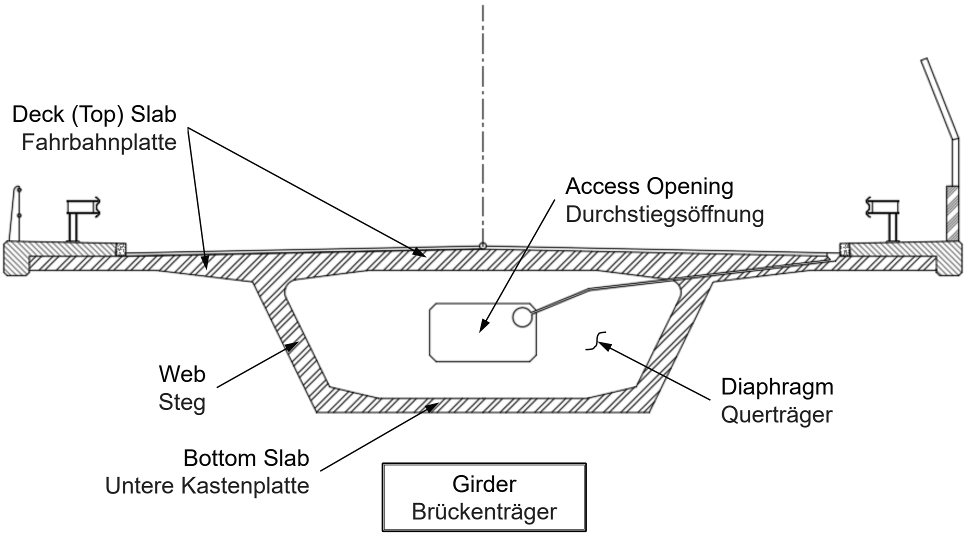
General Characteristics - Nomenclature

Typical Girder Section



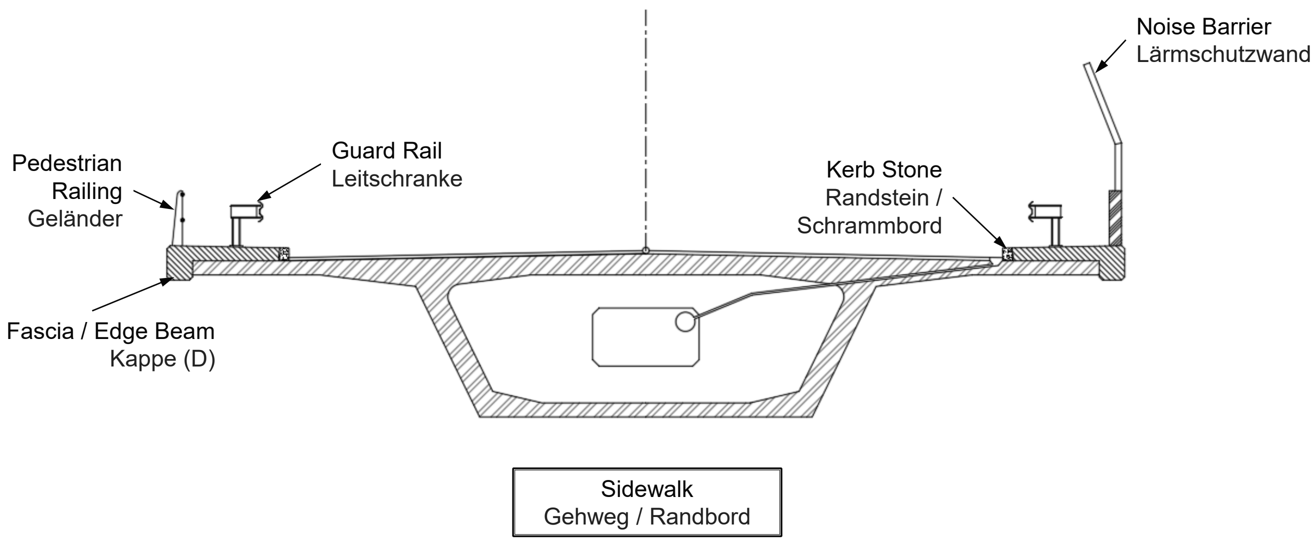
General Characteristics - Nomenclature

Typical Girder Section



General Characteristics - Nomenclature

Typical Girder Section



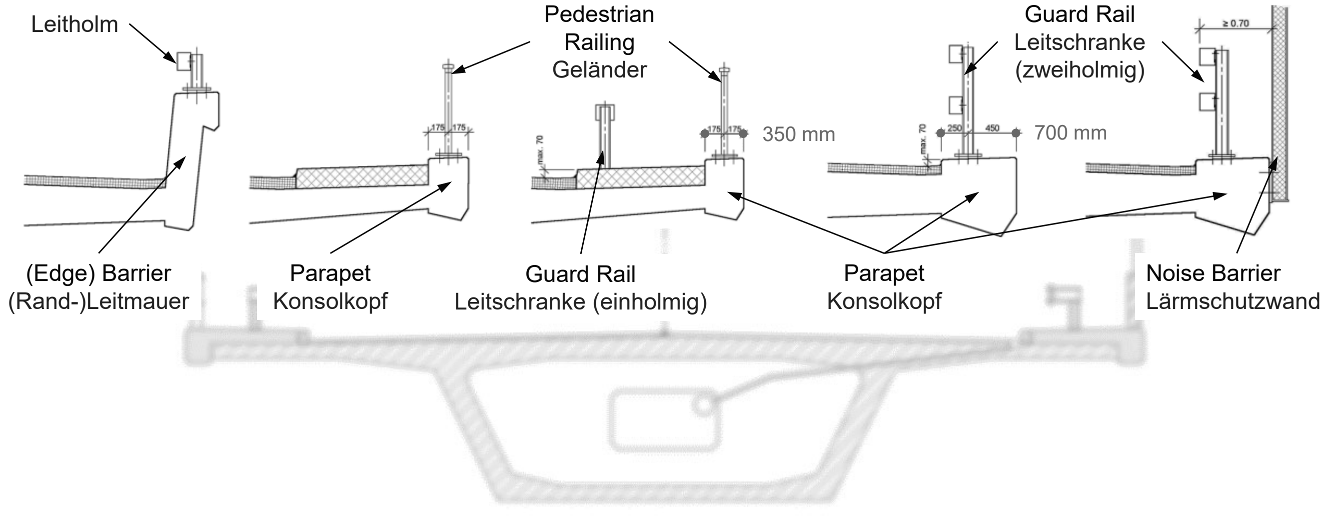
Notes:

The sidewalk width is determined based on the expected pedestrian (or non-motorised) traffic load. In urban areas, and assuming that pedestrians are not served by nearby dedicated pedestrian bridges, the sidewalk should be as wide as 2.0 … 2.5 m (without cyclists). If no sidewalk is required, a minimum width of 0.5 m should be provided for emergency/occasional use. Many clients provide more detailed specifications, see conceptual design (clearances).

The sidewalk can be detailed so that it either acts independently from or compositely with the main girder. In either case, stability of the sidewalk in case of vehicular impact must be considered. If it is not separated from the roadway (occasional or accidental use by vehicles cannot be excluded), the walkways must be designed for full traffic loads.

The need for a guard rail/parapet (steel or concrete) that separates roadway from pedestrian traffic, depends on various parameters such as the bridge setting, i.e. urban vs. rural, the associated speed limits, the inclusion of a bicycle lane on the sidewalk, etc. In case the guard rail is omitted, a minimum height of the kerb should be respected (e.g. 15…20 cm, depending on client guidelines, see e.g. ASTRA RL 12004, chapter “Brückenrand”).

General Characteristics - Nomenclature



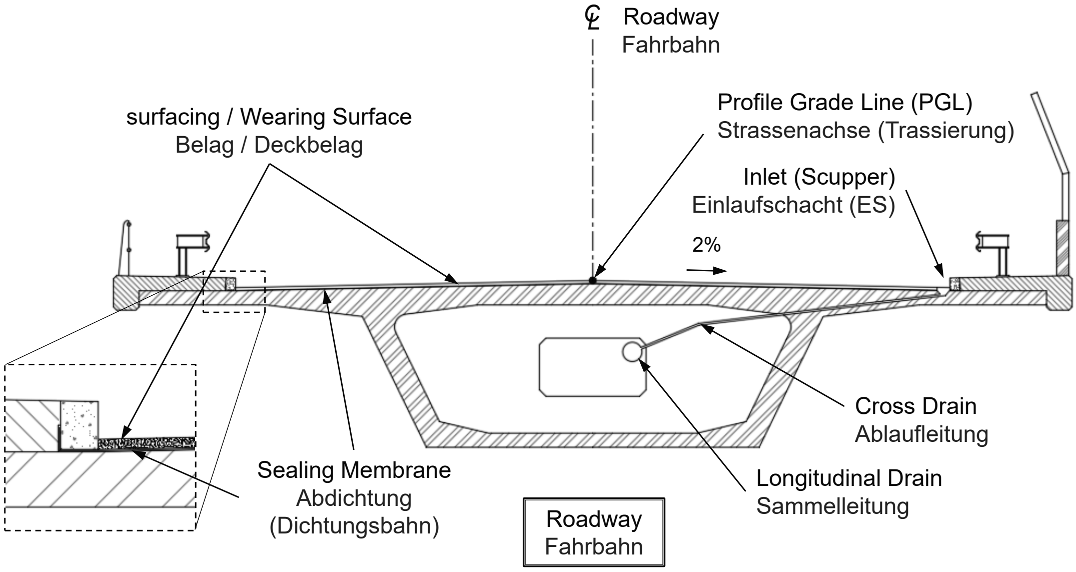
Bridge edges (CH)
Brückenränder (CH)

Notes

Bridge edges (Randabschlüsse) differ strongly depending on location and client. The slide shows typical details used in Swiss road bridges (from Astra Richtlinie 12004, all at same scale). The width of the parapet (700 m) in case of crash barriers is required to ensure that wheels of colliding cars remain on the parapet (the barrier is flexible).

General Characteristics - Nomenclature

Typical Girder Section



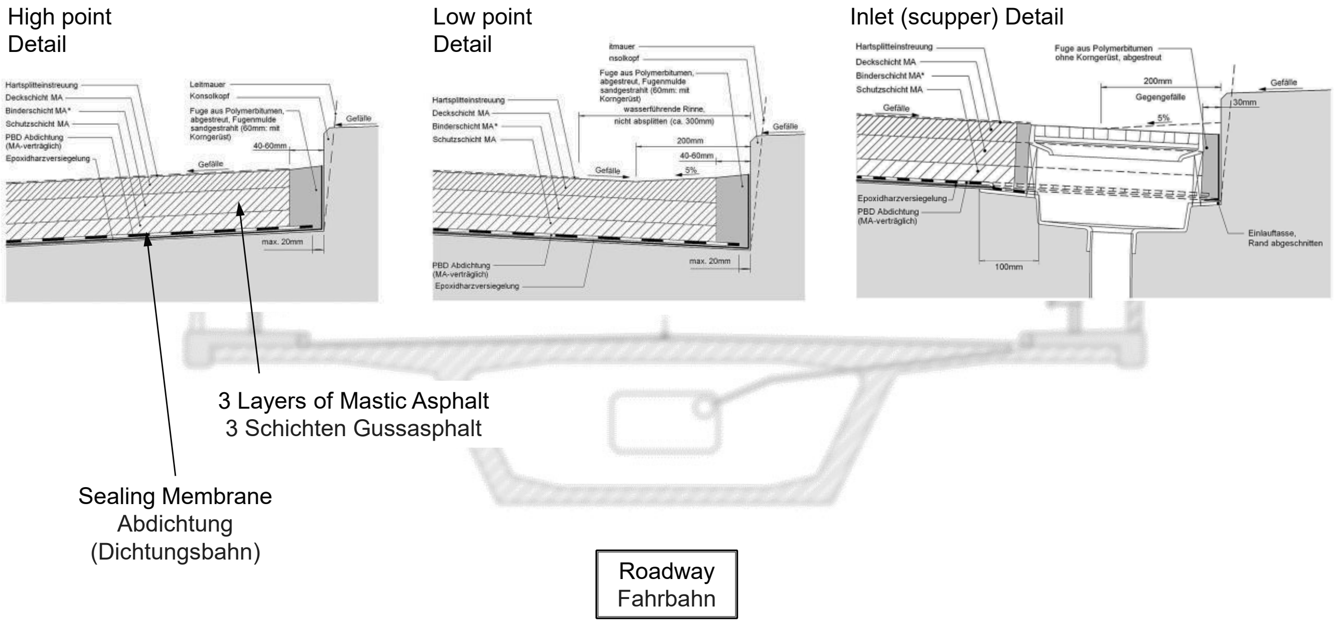
Notes:

The general objective is that the driving experience on the bridge does not defer from that on the road. Therefore, in the case of short span bridges (culverts, spans less than 6 … 7 m) the roadway follows the stratification of a road, e.g. granular compacted base layers followed by a bitumen concrete mix. For longer spans (usual case), the thickness of the roadway is kept to a minimum in order to limit the applied dead loads. A typical layout includes (from bottom to top) a sealing membrane (can be anchored around the kerb stone if present), followed by a membrane protection grout or concrete layer to form the required slopes, and finally the wearing surface (4 … 5 cm thick).

The Profile Grade Line (PGL), developed by the civil (roadway) engineer, defines the roadway geometry in plan and elevation and acts as the reference line around which the bridge superstructure geometry is developed.

Drainage of the bridge deck is typically achieved through of inlets (scuppers). Their location and density depends on the deck slopes (longitudinal and transverse) and the design runoff. Once the runoff is collected at the deck level, it may be directly discharged below through vertical downspouts (if permitted) or guided through a combination of transverse and longitudinal drain pipes to an acceptable discharge location (typically at intermediate piers or beyond the bridge limits).

General Characteristics - Nomenclature



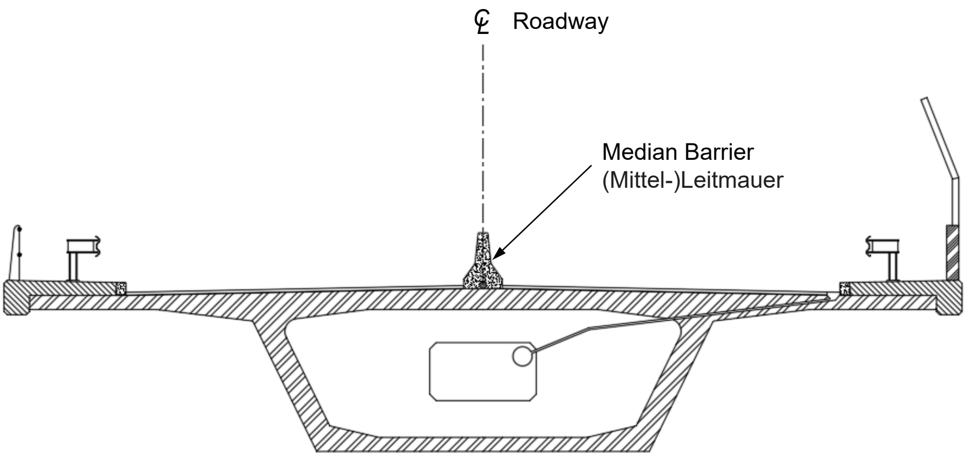
Notes

In Switzerland, three layers of asphalt (mastic asphalt MA or asphalt concrete AC), each 30-40 mm thick, are usually provided on top of the membrane (examples see figure, from ASTRA Fachhandbuch Kunstbauten).

Unlike mastic asphalt (MA), other surfacing types are not watertight. For example, asphalt concrete (AC) is permeable. Even if little water penetrates the surfacing, the surface below the AC needs to be drained to avoid freeze-thaw damages in regions with regular freezing (as Switzerland). To this end, so-called “surfacing drainage tubes” are required. Unless carefully planned and installed, surfacing drainages may cause severe corrosion damage (frequently observed in bridges from the 1960’s in Switzerland). Therefore, it is advisable to use mastic asphalt.

General Characteristics - Nomenclature

Typical Girder Section

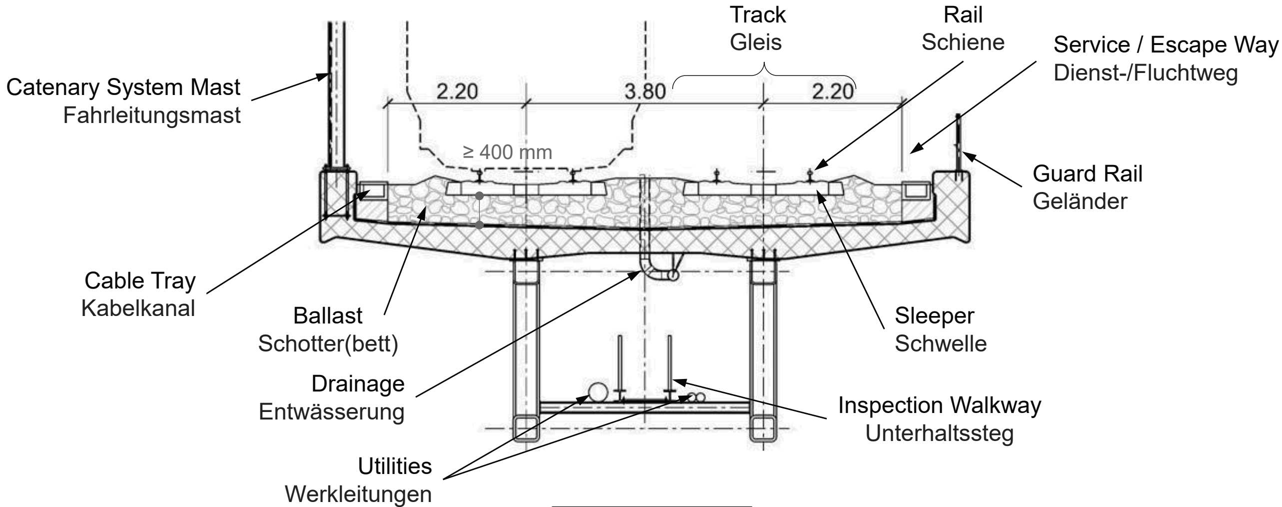


Roadway
Fahrbahn

(With Median Barrier)
(mit Mittelstreifen, Trennung durch Leitmauer)

General Characteristics - Nomenclature

Typical Girder Section



Railway
Eisen-(Bahn)

(Ballasted Track)
(mit Schotterbett)

Notes:

In the case of rail bridges, whenever possible, a ballast layer of about 50 cm (CH: min. 40 cm of ballast between sleeper and deck at rails) is placed on top of the deck slab, followed by the sleepers and rails. The ballast layer acts as an isolator between the bridge deck and the rail system and limits their interaction. This allows for differential expansion/contraction of the deck and the rails and also facilitates maintenance operations along the rail alignment. Whenever it is critical to limit the superstructure dead load, e.g. long-span bridges and/or bridges in regions with high seismicity, or when it is not practical to contain the ballast, e.g. steel truss bridges, the rail system can be directly fixed on the bridge deck (concrete or steel). This type of connection needs special consideration as the interaction between rail and deck needs to be explicitly considered, especially at the bridge ends and at intermediate expansion joints.