

ArcelorMittal Europe - Long Products
Sections and Merchant Bars



ArcelorMittal

Bridges

With rolled sections





Advanced Solutions for Rolled Beams in Bridge Construction

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1. Bridges with Rolled Sections



Footbridge at Bettembourg, Luxembourg –
Single span bridge with a span of 37.5 m
and a precambering radius of 150 m.



Roadbridge in Differdingen, Luxembourg – Bridge with a strong bending over the weak axis (see erection of two main girders on page 7).

There are numerous partners involved when planning the construction of a new bridge. These include:

- the decision-making bodies,
- the residents affected by the construction,
- the bridge owner; the architects and the engineers commissioned by him.

These partners all contribute their own particular experience and ideas to the planning of a bridge.

This brochure outlines how ArcelorMittal Commercial Sections (as a steel producer) can work with you during the early phases of planning the construction of a bridge. It provides precise suggestions and alternatives to put forward at an early stage which contribute to the optimisation of a construction project.

Various methods for constructing short and medium span bridges are presented in this brochure. These cover footbridges and cycle track bridges, as well as road and railway bridges.

The basic element shared by all the construction methods illustrated below is the use of rolled steel sections, in which ArcelorMittal Commercial Sections is the market leader.

Footbridge over the Haken in Hamburg, Germany – Slender bridge with 4 spans of 25 m.



2. ArcelorMittal Commercial Sections



Rolling of a Histar beam in the rolling mill of Differdingen, Luxembourg

ArcelorMittal Commercial Sections, one of the 5 business units of ArcelorMittal Europe Long Products, with plants in Spain, Poland, Czech rep, Romania, France, Italy and Luxembourg, is the largest European manufacturer of hot-rolled sections and has a wealth of experience on a world-wide scale in the production and use of these products.

ArcelorMittal Commercial Sections rolls I-beams, channels, angles and sheet piles. The product range covers all sizes in the European standard series and a large number from the British, American and Japanese standard series.

The largest standard section of ArcelorMittal has a beam height of 1118 mm with a flange thickness of 45 mm. In addition, ArcelorMittal Commercial Sections also produces proprietary sized and "tailor made" sections.



Road bridge over the
A16 motorway, France

3. Steel and Composite Bridges

The planning and construction of bridges has continually exercised a strong influence on the development of the construction industry. Numerous iron and steel bridges are milestones in this development. Some of these constructions have brought world-wide

recognition to their creators, whilst others to this day bear silent witness to their achievement.

Nowadays, long span suspension bridges, cablestayed bridges, truss girder and composite bridges figure among the high points of bridge

construction. In addition to the spectacular constructions, there are also innumerable short and medium span bridges which attest to these continuous developments and highlight the fact that steel is the best choice of material in the construction of bridges.

Multiple span viaduct at Ditgesbaach, Luxembourg



Advantages of Steel and Composite Bridges

Experience shows again and again that, in comparison with other solutions, steel bridges and composite bridges offer significant benefits:

- they are economical, from the point of view of construction and operation, in addition to being well suited for easy, environmentally friendly, demolition and recycling;
- they offer numerous possibilities in terms of architectural design;
- they result in shorter construction times;
- they are also suited to restricted construction depths;
- they enable the approach ramps to be shortened, resulting in cost savings;
- they help reduce construction costs, because the reduced weight of the bridges enables the use of smaller supports and foundations;
- they can be easily adapted to the replacement of older superstructures and, on account of their reduced weight, enable the reuse of existing abutments, etc.;
- they enable the industrial fabrication of construction components under strict quality control conditions in workshops sheltered from bad weather;
- they seldom disrupt traffic circulation because the delivery and erection of the pre-fabricated steel parts can be carried out during off-peak hours;
- they do not obstruct traffic because they do not require scaffolding or temporary supports;
- they are easy to maintain, because the structural components are readily accessible for inspection and maintenance work;



Road bridge in Differdingen, Luxembourg – Erection of two main girders of a composite bridge by crane. The rolled girders are curved along both cross-sectional axes in order to adapt them to the geometry of the road.

- they are flexible because they can be adapted at any time and at low cost to changes in requirements (for example, the widening of traffic lanes or the strengthening of the structure).
- industrial production in the form of high-quality standard products, offering superior availability;
- cost savings due to minimal fabrication costs;
- high fatigue resistance of the hot-rolled products;
- availability of long pieces, reducing the number of site jointing;
- possibility of carrying out finishing work in the rolling mill and consequently of delivering ready-to-install components to the construction site operations.

Advantages of rolled girders in the construction of bridges

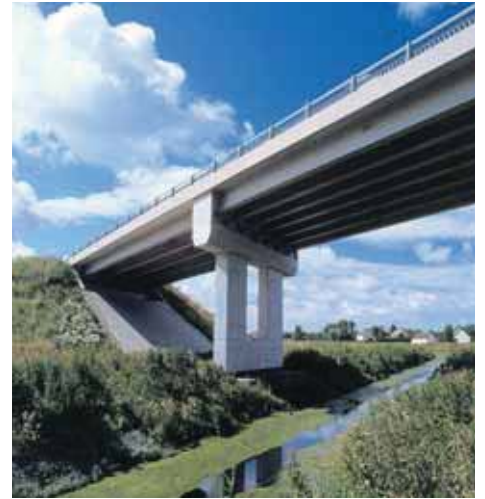
Rolled girders, used in the construction of steel bridges and composite bridges, offer the following distinct advantages:

4. Design and Appearance

Footbridge in Saint-Quentin-en-Yvelines, France - Sophistically designed cable-stayed bridge.



Road bridge in Calais, France - The abutments, bearing piles, load bearing structure, facing plates and guard rails form a harmonised entity plates which lends to the aesthetic quality of the construction work.



With bridges, as with any construction project, the choice of construction materials is influenced or even decided on during the preliminary project phase. It is therefore essential at this stage to take into account the possibilities offered by the use of rolled sections, in order to reap the full benefits of construction using this method. Experience shows that the subsequent elaboration of counterproposals rarely leads to optimised solutions.

During the preliminary planning phase, the specifications and the conditions which will have a decisive effect on the design of the bridge become clear:

- high traffic loads must be safely and reliably carried over the whole service life of the bridge;
- constraints, such as the geometry of the traffic lanes, the clearances, the construction depth, the angle of crossing, etc. demand suitably adapted solutions;
- requirements with respect to the aesthetics of the construction work demand careful design;
- the bridge must often be constructed under difficult conditions, within very tight deadlines and, as far as possible, without disrupting existing traffic circulation;
- all forms of environmental pollution must be avoided;
- the overall profitability of the project must be ensured, while taking into account not only the cost of the construction itself but also the indirect costs, such as maintenance costs and the cost of demolition at the end of its service life.

The planning and design of a construction project constitutes a complex process and demands the full collaboration of all the partners involved, as well as calling upon their professional competence. In particular, there must be a good mutual understanding between engineers and architects.

The purely technical and economical aspects are not dealt with here. They will be tackled in the following chapters where the different construction methods are presented.

Aesthetics

In recent years, increasing demands have been made with respect to the aesthetics of bridges. This trend has also been seen with small construction works which do not come under the category of prestigious projects. A bridge should now be attractive to look at as well as functional. However, there is no standard solution for satisfying this requirement. Careful design must lie at the heart of every construction work and each project has its own parameters, within which the designer can exercise his creative freedom.

The solution sought can be highly diverse, for example:

- fitting the new construction to the surrounding environment, so that it does not dominate visually;
- design of an architecturally uniform work, of which the bridge forms an integral part;
- expression of the stand-alone quality of the bridge;
- harmonisation of the structure with a given living space;
- possibility of adapting the work to future developments.

With rolled sections, the designer has at his disposal a very powerful tool. By making use of their basic properties - in particular high strength coupled with cost effectiveness - he can also include these in a visual statement.

Rolled sections have a simple linear form and feature even surfaces. They lend a clean and precise form to the structure, which is enhanced by the fine aesthetic nuances of the different surfaces. Stiffeners, which are often seen as disruptive to the aesthetic harmony of a work, are in general not required due to the excellent static properties of these rolled sections.

Bridges constructed using rolled sections are distinguished by their lightness. As the ratio of span to apparent deck depth is high, the bridges have a slender profile and the resulting impression of transparency plays a major role in the overall aesthetics of the work.

By bending the beams, it is possible to adapt them to the desired line. Moreover, the designer can make use of the possibilities to construct more pronounced curves, notably for footbridges.

Structures built using rolled sections are visible and easy to “decipher”. The observer unconsciously visualises how the loads are carried by the structure and appreciates both the functionality and aesthetics of the work.

The general form of a bridge is essentially conditioned by the form of its components and its proportions, in terms of span, construction depth, height of opening, and pier and abutment volumes.



Footbridge near Schifflange, Luxembourg – Principle beams with an extreme curvature.

4. Design and Appearance



Composite bridge with concrete crossbeams at Bentwisch, Germany – Design combining steel and colour.

The characteristics of rolled sections offers great flexibility, which opens up numerous possibilities with respect to spans, slenderness, choice of line and reduced dead weight of the load bearing structure.

The load bearing structure and other bridge parts should work in harmony. On account of their form and the visual quality of their surface, steel sections harmonise perfectly with guard rails, safety barriers, acoustic screens and face plates.

The visual impact of a construction work is often influenced to a large extent by the choice of colours used. In this field, endless possibilities for making an aesthetic statement are opened up by painting the metal. Following the development of new types of paint, this use of visual expression is today being used more and more often. The final result depends both on the choice of colours for the different components and on their harmonisation with each other and with the surrounding environment. Furthermore, if the bridge is repainted during the course of maintenance work, new colours can be used in order to give it an appearance which is at once new and different.



Footbridge over the A13 motorway at Soleuvre, Luxembourg – Design combining steel and colour.

5. Composite Bridges



Road bridge over the A16 motorway, France - Composite deck with two main girders in high strength steel S 460 M.

Principle

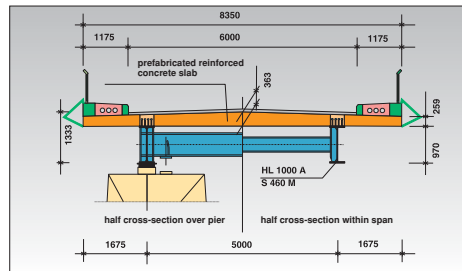
Composite deck construction consists of steel girders which support a reinforced concrete slab. Composite action is achieved by connecting both materials by shear studs. Transverse bracing over supports provides lateral restraint.

Applications

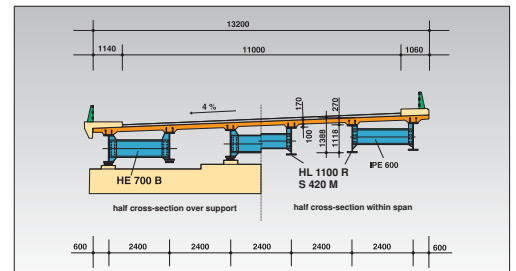
Composite deck construction is recommended wherever construction depth is not, or only slightly, restricted. Feasible spans for road bridges range up to about 35m for simply supported spans and up to about 40 m for continuous spans.

Cross section

For a narrow deck, two main girders are required. When the deck is wider or when construction depth is restricted, more than two girders will be needed.



Example of twin girder arrangement (cross section of A16 overbridge)



Example of a 6 girder arrangement (cross section of roadbridge, by-pass for the town of Luxembourg)

If an extraordinary torsional stiffness of the main beams is needed box sections can be used as alternative to single beams. These box sections are built from two parallel rolled girders joined longitudinal with a weld between the flanges or by a concrete infill in the chambers of the beam.



Bridge link with two spans of 23.9 m to La Sarre, Luxembourg – The composite bridge is a twin-girder bridge with box sections of two longitudinally welded rolled beams.



Bridge link to La Sarre, Luxembourg – The large cantilevers have been designed to support the prefabricated concrete elements during construction without any scaffolding, the box sections have been designed to resist the resulting torsional moment.



Gosnat bridge in Vitry, France

Statical system of main girders

Girders of single span bridges are simply supported on the abutments. Multiple span bridges are designed either as successive simply supported or as continuous structures.

Continuous girders are statically better suited: bending moments are lower and deflections are smaller. In addition they offer a major constructional advantage: the number of bearings and expansion joints, which cause high costs by the need for regular maintenance, is reduced.

Continuity

Depending on the overall bridge length and transport conditions the beams may be erected as unspliced pieces (delivered ex works in lengths up to 34 m or in exceptional cases up to 45 m) or site splicing will be necessary. In the latter case both splicing by butt welding and by bolting (high strength friction grip bolts) have proved successful.

VDN bridge in Dakar, Senegal



An alternative method consists in connecting the beams to a concrete cross girder through end plates and additional slab reinforcement (see page 15 Transverse bracing ensuring continuity).

Cambering and bending of main girders

Girders are cambered to compensate for deflections under permanent loads. Additional bending may be required to form the girders to the shape of the longitudinal profile. If the bridge is horizontally curved bending along the weak axis may be necessary. Both cambering and bending are carried out in the rolling mill on a press.

Steel grades

Steel with a yield strength of 355 N/mm^2 (S 355) and more recently of 460 N/mm^2 (S 460) are used primarily. With the latter type, special attention should be paid to the stiffness requirements.

The use of S 460 high-strength steel in place of the more traditional S 355 results in a substantial reduction in weight and corresponding savings in material costs. Fabrication costs are also lower, with a full butt joint, for example, the weld volume is considerably reduced.

Steel subgrades

The use of fine grain structural steel is particularly advantageous: for example, grade S 355 M/ML or grade S 460 M/ML in accordance with EN 10025-4 and HISTAR Trademark Steels. More information on HISTAR can be found on our website: sections.arcelormittal.com

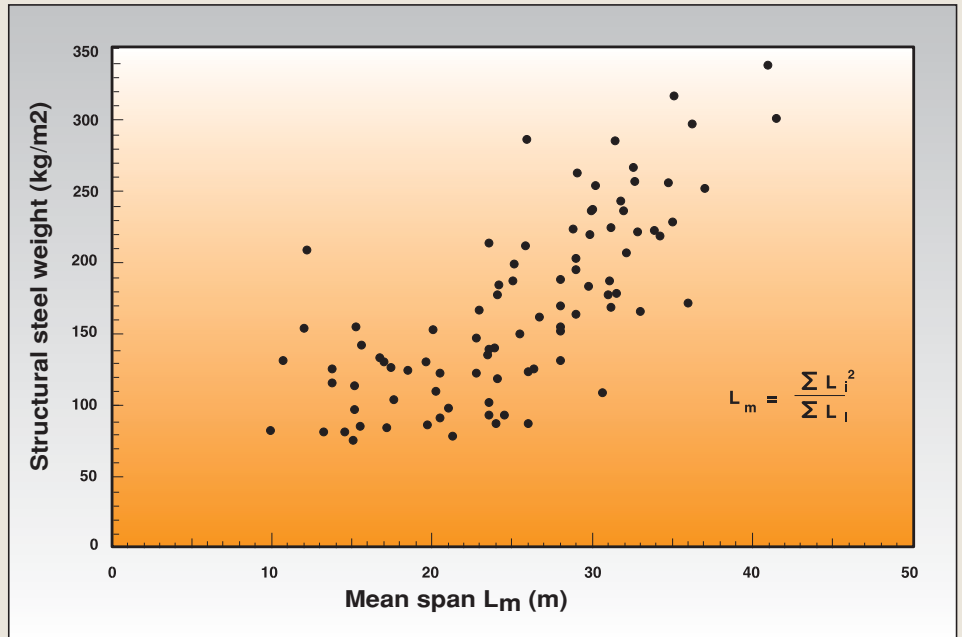
Shapes made from these low alloy fine-grained steel are produced using a thermo-mechanical rolling process with an increased cooling rate and subsequent self-tempering. These grades demonstrate excellent toughness at low temperatures and are characterised by their outstanding weldability. Due to the low carbon equivalent value, pre-heating is not required before flame cutting and welding. Also steels for low temperatures and weathering steels are available.

Transverse bracing at supports

At supports, bracing is required to transfer horizontal loads to the bearings and to provide lateral and torsional restraint to the girders. Bracing is often designed to carry additional jacking loads in case of replacement of bearings.

Bracing consists of:

- either steel beams which are moment - connected to the main girders by bolting or welding
- or reinforced concrete cross beams, where the reinforcing steel passes through drilled holes in the web of the longitudinal girders. Concrete cross beams are used with direct or indirect support.



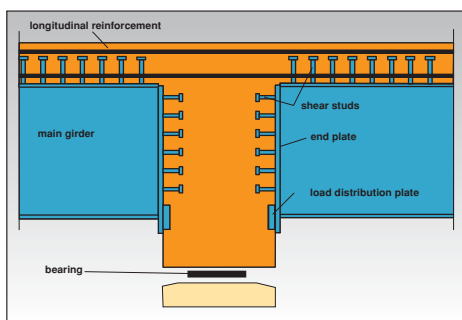
Composite road bridges. Structural steel weight per square metre of deck area.



Road bridge in Bremgarten, Germany - With concrete cross beams and indirect support.



Railway bridge over the A23 motorway in Fretin, France - Four-span bridge with spans of 16.9 - 21.9 - 23.0 - 17.8 meters. The two continuous main girders and the bracings within spans are rolled beams; the cross beams at supports are made of reinforced concrete.



Concrete connection of main girders - Cross section through bracing (schematic)



Bridge in Schwedt, Germany - Concrete connection of main girders.

Transverse bracing ensuring continuity

Reinforced concrete bracing over intermediate supports of multiple span bridges may be designed as splices of longitudinal girders. This construction method combines the following advantages:

- the longitudinal girders are erected as single span girders;
- there is no need for welded or bolted splices.

Continuity is achieved by the use of vertical end plates and additional reinforcing bars in the deck slab. During concreting loads due to the dead weight of steel girders, formwork and wet

concrete are carried by simply supported beams. After the concrete has hardened, moment resistance is provided at splices and subsequent loads are supported by continuous girders. Thus hogging bending is produced at supports only by super-imposed dead loads and variable actions. Forces are transmitted as follows:

The compressive force is directed through the end plate from the lower flange to the concrete. The tensile force flows from the upper beam flange through the shear studs into the longitudinal slab reinforcement. Studs welded to the vertical end plates transfer the shear force from the steel beams to the concrete bracing.

Intermediate transverse bracing

Vertical loads are laterally distributed by the means of the deck slab. Bracing within the span is needed to stabilise the girders, but does not participate in load distribution.

During construction, bracing prevents girders from lateral torsional buckling in sagging moment regions. After hardening of the

concrete, the slab takes over this stabilizing action and bracing may be removed. With continuous girders, lateral buckling of the lower compression flange in hogging moment regions must be avoided. This is achieved using the bracing at the supports and, if needed, additional intermediate permanent bracing.

New public transport system in Oberhausen, Germany - Crossing the DB railway line.



Composite bridge over busy railway line in Choisy, France – A pair of ready-to-erect girders are transported to the construction by rail.

Deck slab

The deck consists of a non prestressed concrete slab with longitudinal and transverse reinforcement. Longitudinal reinforcement of continuous decks must be specially designed for crack width control.

Hogging moments of two and three span bridges may be reduced by lowering the structure at intermediate supports after concrete hardening.

These operations can be carried out at the rolling mill's finishing department in a both cost effective and time-saving process. Alternatively the work can also be carried out fully or partially in a steel fabricators' workshop.

The ready-to-erect girders are transported to the construction site by rail or by lorry. The single components are relatively light and therefore only low capacity lifting equipment is required on site.

Bearings and supports

In general, simple elastomeric bearing pads are used with composite bridges. The advantage of the low construction weight of composite construction results in smaller dimensions for the sub-structure, including abutments, piers and foundations (in particular, pile foundations). The resulting savings in construction costs are characteristic for this construction method.

The girders are often pre-assembled in pairs in order to get erection units with increased stability. The girders or pairs of girders are lifted into final position by mobile cranes. Alternatively elements are assembled in a nearby area and subsequently launched.

The low masses of steel components enable rapid assembly of the structure. In most cases, there is no need for temporary supports. When the routes crossed are in service, disruption to traffic can be kept to a minimum, especially if works are scheduled during off-peak hours.

Fabrication, transport and erection

Fabrication consists of the finishing of the rolled beams, i.e. cutting to length, drilling, cambering or bending about the strong axis and, if required, about the weak axis, welding of shear studs and bearing plates, surface preparation and application of a corrosion protection system.

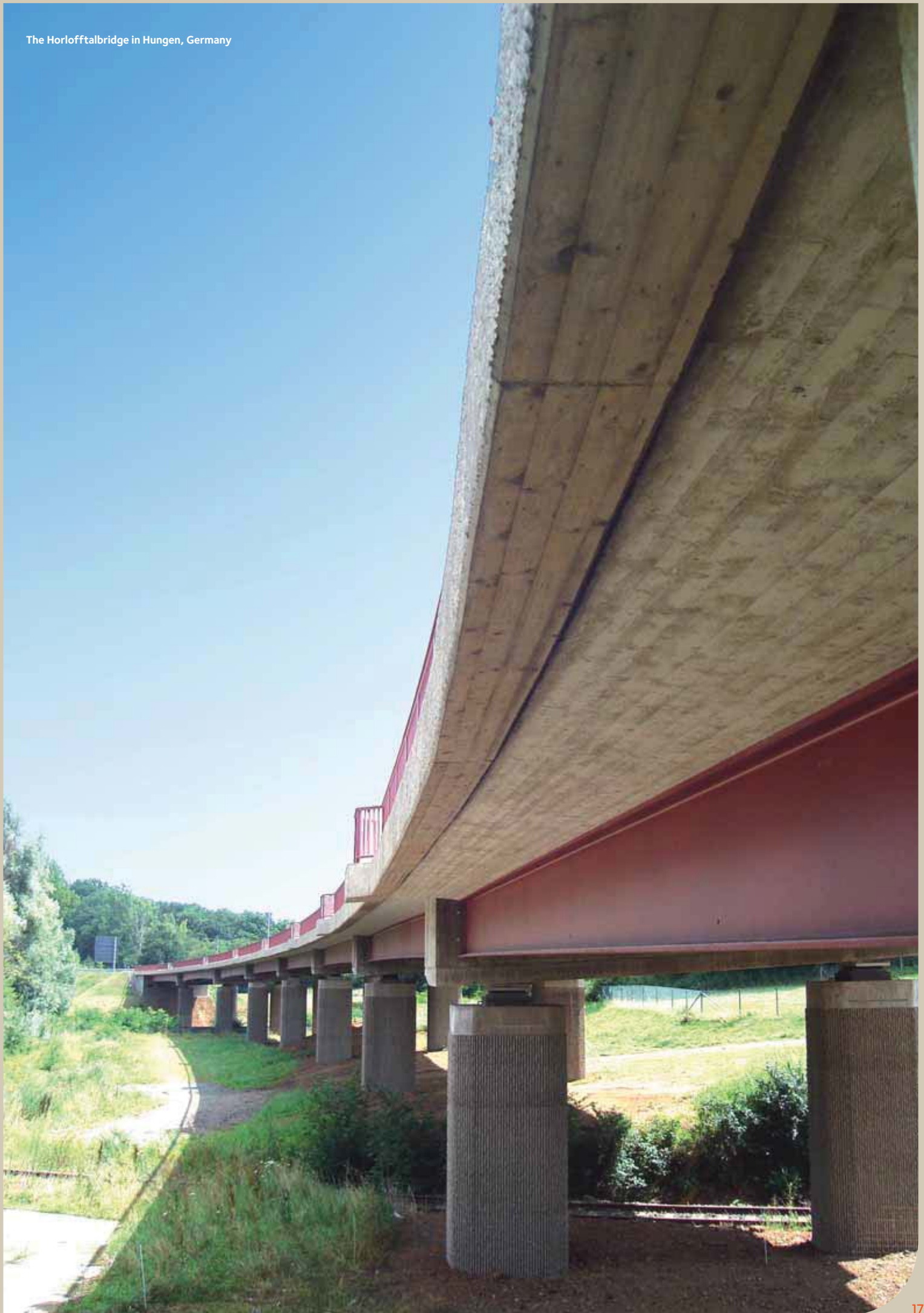
Composite bridge in Choisy, France – Lifting in of two pre-assembled girders early in the morning.



Railway bridge over the A23 motorway in Fretin, France - Launching of the steel structure and assembled formwork.



The Horlofftalbridge in Hungen, Germany





Precast reinforced concrete panels used for permanent formwork.



Example of formwork support for cantilever part of slab.

In-situ Concrete Slab

The concrete slab can be cast in situ either on reusable formwork, or on precast concrete planks or profiled steel sheeting.

If certain conditions relating to construction and reinforcement are complied with, the precast planks contribute to carrying loads in the transverse direction, together with in situ concrete. For cantilever parts, traditional formwork is generally used, with supports attached to the edge beams.

Prefabricated Slab

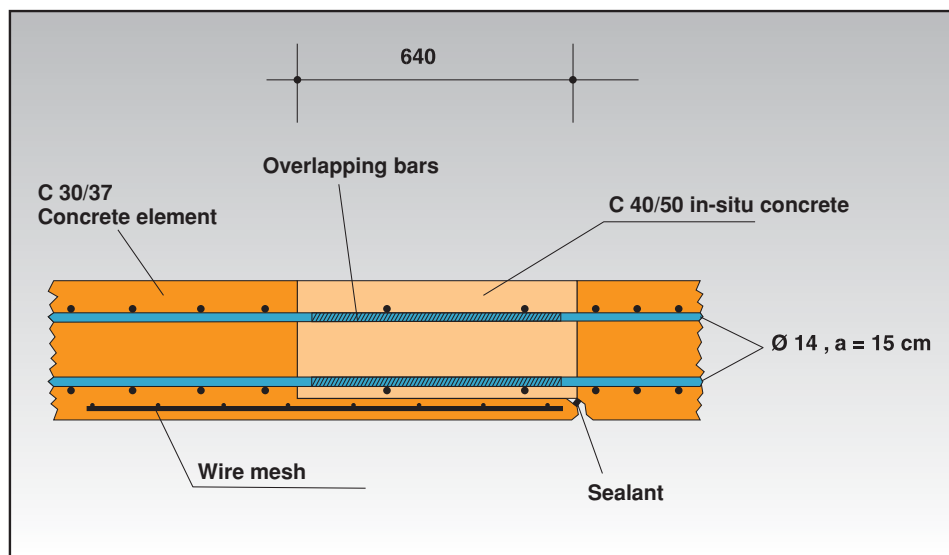
As an alternative to in-site concreting, precast deck elements can be used. The main advantage of this method consists in the reduction of the number of site operations and a substantial saving in the construction time.

With twin girder - type bridges, the precast elements span the full width of the bridge as a single component. To allow connection with steel girders, slab elements may have pockets for shear studs.

The prefabricated elements are placed in a mortar bedding on the girder flanges. Alternatively support may be designed with a small gap between flange and slab which is later filled in with grout.

Consequently transverse joints and pockets are filled with concrete to connect the slab to the steel structure.

Hogging moments in continuous span girders can be reduced by lowering (jacking) the structure or intermediate supports after hardening of the concrete. The slab is prestressed longitudinally.



Prefabricated slab. Example of transverse joint detailing.



Prefabricated slab – erection of a precast concrete element.



The Horlofftalbridge in Hungen (Germany) with eight spans constructed in 2006. For five spans partially prefabricated concrete beams with heavy rolled beams in S460 have been used.

Prefabricated composite beams

Short construction time is essential if disturbance to existing traffic should be minimized. This requirement is met through prefabrication of composite elements which are light, and therefore easy to handle and to transport.

The main advantages of the prefabricated concrete flange hereby are:

- Stabilizes beam (transport and construction),

- Braces not needed for casting of concrete,
- Scaffolding not necessary,
- Stiffeners usually not required.

Further benefits for this type of construction are:

- Steel contractor on-site superfluous,
- Manufactured in workshop conditions,
- Composite actions already in construction period.

Thus the quality of the structure increases substantially. The elements can still be lifted and placed with a light-weight crane (compared to the heavy weight of pre-stressed concrete girders). The overall construction is extremely efficient and the construction time is optimized.

The Horlofftalbridge in Hungen, Germany - Lifting in of a partially prefabricated beam.



6. Filler Beam Decks



Bridge at
Sète-Frontignan,
France

Principle

A filler beam deck consists of a concrete slab with stiff longitudinal reinforcement made of rolled beams and transverse reinforcement of steel bars.

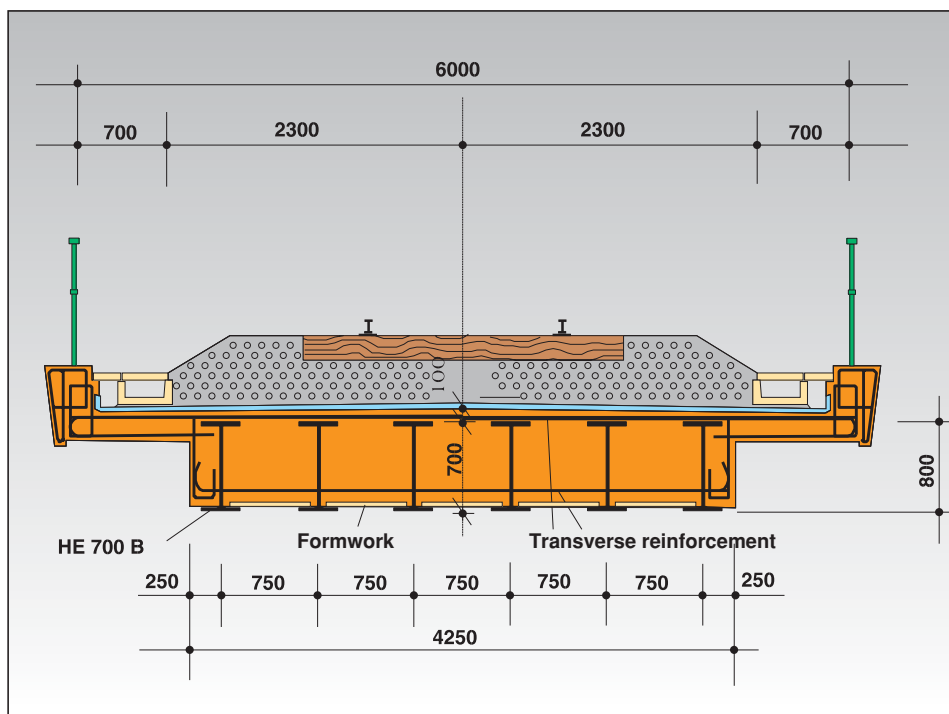
Closely spaced steel beams and concrete act compositely. Specific mechanical shear connection is not required provided that beams are cleaned to remove mill scale and that certain, mainly mill geometrical requirements, are met (refer to codes).



Multiple track railway bridge in Nienburg, Germany - The longitudinal profile of the road and the tracks greatly restrict the available construction depth.



Construction of a filler beam railway bridge as part of the Puymorens road tunnel link between France and Spain.



Typical cross-section of a single track railway bridge.

Applications

Originally developed only for railway bridges, over the last few decades filler beam decks have also been widely and effectively used for road bridges. It offers a robust, simple and durable construction which does not require any highly specialised labour. Due to their high load carrying capacity, there are now a large number of decks of this type still in use even where the service conditions have changed.

Filler beam construction is recommended:

- for bridge decks with restricted or very shallow depths;
- for bridges crossing roads with high traffic density: erection is both quick and easy; temporary supports and falsework are not required, so that disruption of traffic can be avoided to a large extent;
- when replacing decks in existing structures: the shallow slab thickness facilitates adaptation to the geometrical constraints. Furthermore, the monolithic construction is also well suited to erection by launching.

The span covered by filler beam decks range

- up to 40 (50) meters for road bridges;
 - up to 30 (35) meters for railway bridges;
- (figures in brackets apply for continuous multiple span bridges).



Multiple span filler beam bridge for the approach viaducts to the crossing of the high speed railway line LGV Est over the Moselle river.

Overbridge at motorway Interchange in Fameck, France -
Beams are bent horizontal to match road curvature.





**Filler beam deck bridge in Esch-sur-Alzette, Luxembourg - 19 m span; 0.65 m deck depth.
For aesthetic reasons the edge beams are not encased in concrete on the outer side.**

Design

Considering the bridge deck in the longitudinal direction, a composite structure is assumed for the design. In the transverse direction the deck behaves as a reinforced slab. For ultimate limit state, plastic moment resistance may generally be considered with concrete in tension being neglected. For the calculation of the deflections due to superimposed dead loads and live loads, a partial contribution of concrete in tension to flexural stiffness is taken into account. Fatigue strength of non-welded parts need not to be checked.

Steel grades S 235, S 275 and S 355 are commonly used. For long spans, vertical deflection under traffic loads usually does not govern the design. Hence high strength grades S 420 and S 460 provide cost advantages.

Beams

Longitudinal reinforcement of the slab consists of rolled I-beams. The web spacing does not exceed 75 cm. A clear distance of at least 15 cm between flanges is needed to allow pouring of concrete. The upper flange is encased in concrete with a cover of 7 to 15 cm, but not exceeding 1/3 of the nominal section depth. After completion of the deck, only the soffit of the lower flanges remains visible.

Beams need to be cambered for two reasons: to compensate for dead load deflection and to allow the deck shape to follow the longitudinal profile of the road or track. In case of a curved deck supplementary bending about the weak axis may be required. Both cambering and bending may be carried out at the rolling mill's finishing department.

With multiple span bridges, structural continuity is generally preferred to simply supported decks. For this purpose beams are either:

- delivered to site and erected in full length, if allowed for by production, transport and erection possibilities;
- or spliced on site.

Connections may be carried out as bolted cover plate splices or as butt-welded splices. Usually they are located within spans at a section with low bending moment, and they are staggered.

In order to maintain beams in position during concreting, spacers (for example threaded rods) should be provided. Stability against lateral torsional buckling under dead load (of steel and wet concrete) must be checked. Concreting may be carried out in more than one stage and/or transverse and plan bracing may be needed.

Lower side of a filler beam deck - Only the bottom flanges of beams are visible.



6. Filler Beam Decks

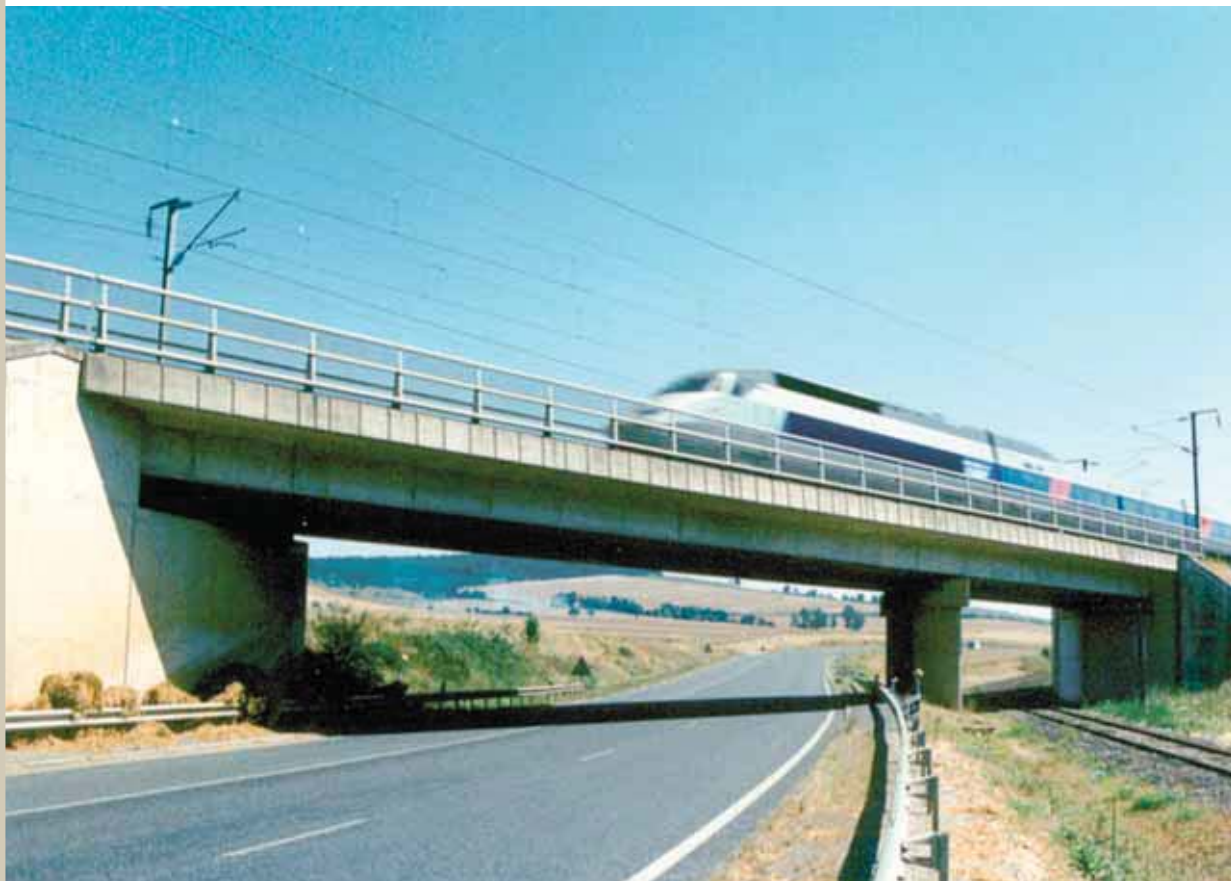


Reinforcement

In transverse direction non-prestressed reinforcing bars contribute to carry the loads.

The lower bars are threaded through holes in the steel webs whereas the upper bars pass over the beams. Both reinforcements are anchored beyond the outer beams. Stirrups and reinforcing bars in longitudinal direction are added according to the statical requirement or for the control of cracking.

Filler beam deck bridge in Amsterdam (Dutch State Railway Company).



Bridge for the high-speed track of the LGV Ouest, France



Pont de Cyrnos in Senegal -
Detail of the support.

Bearings

Simple elastic bearing pads are provided for each beam. The number of bearings may be reduced by the use of an integrated cross beam which requires additional reinforcement bars.

Fabrication, transport and erection

Fabrication consists in finishing of beams in a few simple operations which may all be carried out at the rolling mill's finishing department: cutting to length, drilling of holes, cambering, welding of bearing plates (if any) and application of corrosion protection on lower flange.

Beams are delivered to site ready for erection. Beam length may reach commonly 34 m. In exceptional cases they can be supplied (by rail) in lengths of up to 45 m. Due to low unit weight, only small cranes are needed.

Pont de Cyrnos in Senegal - Bottom view on the filler beam deck and support.





Railway bridge at Berchem, Luxembourg



There are various proven methods for the construction of the bridge decks. These include the following:

- lifting of beams into final position and assembling of spacers and bracing;
- assembling of beams on an area located behind the abutment and subsequent launching;
- erection of beams alongside final location on temporary supports, concreting of the deck and finally sliding into position.

The last method is often used for the replacement of old decks.

All these methods cause only minimal disruption to existing traffic.



Construction of an overbridge of A104 motorway, France – Falsework is not required. Disruption of motorway traffic is minimal.

Railway bridge of the TGV Atlantique high speed line in Massy, France – Launching of the beams over the A10 motorway interchange.



Formwork and concrete

The formwork consists of prefabricated fibrecement or concrete planks which are placed on the lower flanges of the beams. A sealing mortar bed or rubber strip is used at the support. For the slab edges traditional formwork is attached to temporary supports. Prefabricated permanent formwork units may also be used.

The space between beams is entirely filled up with concrete and the upper flanges are encased with a minimum cover of 7 cm.

With deeper beams concreting is carried out in two or more steps with a first layer of at least 15 cm thickness. This helps to prevent beams from lateral torsional buckling. Temporary props are not needed and construction can be completed without disturbing traffic under the bridge.

6. Filler Beam Decks



Railway bridge at Sète-Frontignan, France -
Lifting in of a pre-assembled part over
an existing railway line.



Full moment rotation joint with bolted cover plates.



View on support.



Assembled first span over the existing railway line.



Railway bridge at Sète-Frontignan, France

7. PreCoBeam Bridges



Cross Section alternative of the PreCoBeam designed by SSF Ingenieure, Munich.



Oxycutting of a rolled beam (HD 400x421 in S460) with the shark fin shape for the PreCoBeam bridge at Vigaun, Austria.



Separation of a PreCoBeam in the finishing shop of ArcelorMittal.

The PreCoBeam (Prefabricated Composite Beam) solution is a new bridge construction method invented in the beginning of the new millennium. It is again an example for economic bridge solutions with rolled beams and a high degree of prefabrication. This method is based on a rolled steel beam, oxy-cut longitudinally in two T-sections with a special shape. This shape works as a continuous shear connector which allows for the shear connection between profile and slab without the use of studs, and thus without any welding.

After cutting, corrosion protection on the profiles on the parts exposed to the atmosphere in the final stage. In the next step reinforcement bars are placed through the cutting shape and a concrete top chord is concreted in the shop to produce a prefabricated bridge element. Subsequently the prefabricated bridge elements are transported to the site, placed on the abutments and, finally, the residual concrete chord is added on-site.

The method is a very flexible solution offering various cross section possibilities according

to the design requirements. As a result, the PreCoBeam, with the use of state-of-the-art continuous shear connectors and integrating the advantages of prefabricated element bridges, meet the following targets for competitive and sustainable construction:

- high safety standard for vehicle impact, especially for bridges with only two girders (shock),
- reduction of coating surface,
- elementary steel construction nearly without any welding,
- sparse maintenance and easy monitoring.



PreCoBeam used for the bridge at Vigaun, Austria.



Lifting-in of a PreCoBeam for the bridge at Vigaun, Austria.



The Vigaun bridge made of PreCoBeams with three spans of 26.15 m and a slenderness ratio of 1/23.

8. Prestressed Composite Girders



Single span bridge in Kerpen Horrem, Germany - 41.25 m long HE 1000 A beams used for prestressed composite girders of "Preflex" type.

Principle

When a rolled beam is bent the tension flange is elastically stressed. In this state it is encased in concrete. Shear connections are provided for composite action.

After hardening of the concrete, bending is released. The concrete part is thus compressed - it is prestressed.

After erection on-site the other flange is connected to the concrete slab. By this procedure double composite action is given.

A two-fold aim is achieved:

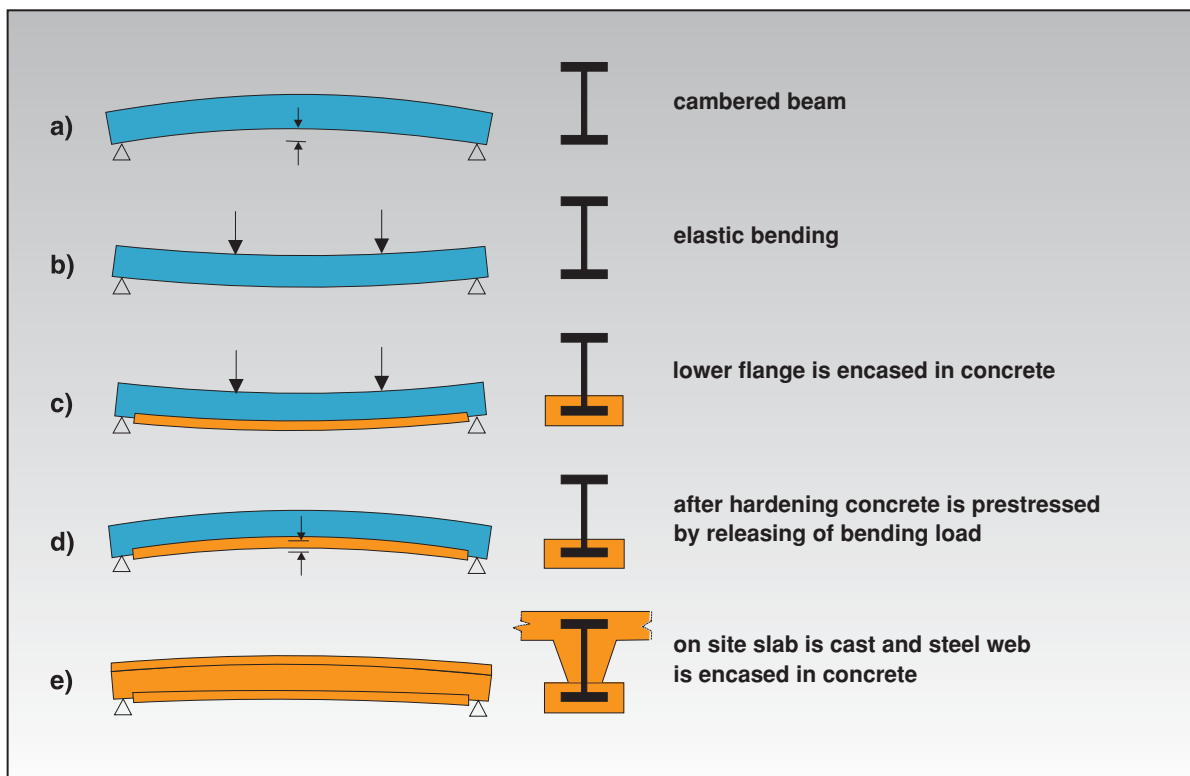
- the concrete slab increases the bending capacity and stiffness of the girder;
- under service load pre-compression stress in the concrete of the lower flange is reduced, but not totally. Thus no cracking occurs; concrete of the lower flange increases the flexural stiffness and reduces deflection.

Applications

Prestressed composite girders have:

- a very high moment capacity; they are suited to the construction of bridges carrying heavy loads, in particular railway bridges;
- a very high stiffness; deflections under service loading are small.

Due to these properties, prestressed girders are particularly suited to structures when the available construction depth is highly restricted. The slenderness ratio value (ratio of the span divided by the structural depth) may reach 45 for road bridges.



Fabrication of prestressed composite girder.

Fabrication and Erection

Beams are cambered at the rolling mill.

At the fabrication shop shear connectors and additional cover plates (if any) are welded to the flanges. Then elastic bending, encasing of lower flange with concrete and prestressing are carried out as described above.

Most prestressed composite girders are simply supported beams. Sometimes girders are spliced at supports for continuous action.

After erection of the prefabricated girders formwork elements are placed on the lower flanges. They are specially shaped for casting of the slab and simultaneous encasing of the steel webs. Thus a protective treatment against corrosion is not necessary.

If particularly high loads are to be carried (for example railway loads) prestressed composite girders may be arranged side by side. No formwork is needed. By encasing in concrete girders are integrated into a massive slab.

9. Half-through Girder Railway Bridges



Half-through girder
railway bridge at Orgon, France

9. Half-through Girder Railway Bridges



Railway bridge over the Emile Mark street in Differdange, Luxembourg - The replacement of an old deck with direct track fastening by a ballasted track bridge required a structural system with minimized construction depth. A half-through girder deck solved the problem. The picture shows the assembled steel framework before concreting.



Reconstruction of the railway bridge over EmileMark street in Differdange, Luxembourg - Because of the very restricted construction depth, two single track half-through type bridges were implemented.

Principle

Main girders are arranged on both sides of the track. Their lower flanges support a floor with a ballasted track.

Applications

Half-through construction is appropriate if available construction depth is very small. Rolled beams used as main girders cover single spans up to about 16 m for standard track. For multiple track lines separate decks may be built without a need for increasing the track spacing.

This construction method is suited for both the construction of new bridges and the replacement of existing decks. Also old decks with direct fastening of the track can be replaced in decks of modern form with ballasted track. Single span decks may be completely prefabricated and brought into position during temporary possession with minimal disruption to trains.



Renovation of the platform in the main station in Zürich - The new 5-span decks for ballasted track are of half through girder type with rolled beams and a reinforced concrete slab supported on lower flanges. Available time and space dictated the erection procedure. The 69 m long beams were lifted into position with portal cranes.



This example shows a bow-string bridge for the Mediterranean high speed railway line over the French highway A7 near Avignon (F). A filler beam deck has been used to span transversally to the bridge axis.





LGV Est bridge, France

Design and construction

Main girders of short span are rolled beams. For longer spans built-up sections have to be used.

The floor between the girders is of filler beam type. Rolled beams are arranged as cross girders in a close spacing and are encased in concrete. Only the lower flanges that carry the permanent formwork are left exposed. This method minimizes the construction depth of the floor which transfers the loads to the main girders. Filler beam floors are therefore well suited also for double track bridges.

The inner side of the web of the main girder web is also encased in concrete. The resulting concrete trough maintains the ballasted track. For lateral stability of main girders, part of the cross beams are rigidly connected to the main girders to form U-frames.

The floor may also be a common reinforced concrete slab. A few cross beams and bracing are then required for stability during construction.

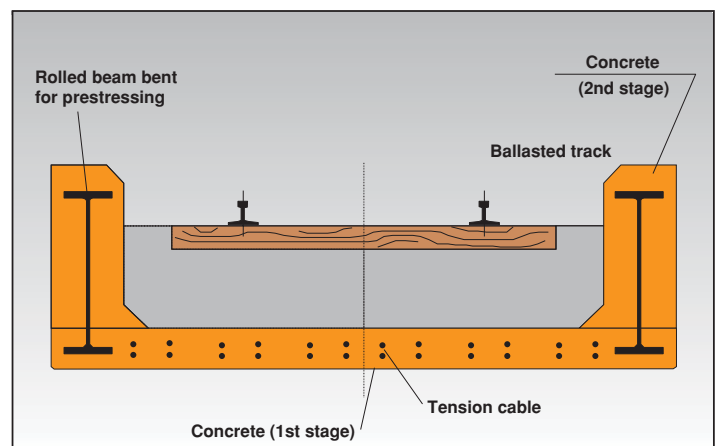
The prestressing method described may be applied to the main girders and the encasing slab in order to reload the concrete (SNCB-NMBS system). The resulting structure is extremely stiff.



A half-through girder deck during launching. It carries the new Mediterranean High Speed Railway Line which was opened to traffic in 2002. The exposed flanges of the transverse filler beams can be seen at the bottom side. The blue coloured part is the launching nose.



Extension of the Brussels - South Station for the Eurostar trains - A launching gantry is used for fast erection of prefabricated prestressed composite decks.



Typical cross-section of a half-through prestressed composite deck - This system of prefabricated deck has been developed by the National Belgian Railway Company (SNCB-NMBS).



La Savoureuse bridge, France

10. Truss Girder Bridges



Reconstruction of the bridges over the Muota river, Gotthard -line of the Swiss Federal Railway Company - Diagonals and upper chords are made of rolled beams (HD and HE shapes). Thermomechanically rolled steel was used for enhanced weldability.

Steel truss girders are particularly well suited to the construction of medium span bridges, offering high strength and stiffness combined with low dead weight. They consist of slender elements opening up a wide range of possibilities in terms of overall shape and resulting in a light and transparent structure.

Steel trusses have also proved effective and economic in the construction of short span bridges in remote sites which are not readily accessible. The low weight of components greatly facilitates transport and erection.

Design and construction

The easiest arrangement of the deck is at top chord level. The concrete deck slab, if connected to the steel girders, acts compositely.

If available construction depth is limited, through or half-through arrangements are chosen.

Nowadays, parallel chord trusses are often preferred. Typically diagonals are inclined at the same angle. There are no verticals. Connections are standardised as far as possible for cost-effective fabrication.

An alternative method to traditional design of truss member connections arises from the geometric properties of rolled beams.

Chord and diagonal sections with different sectional areas but the same inner depth between flanges are arranged in a way to allow butt welding of flanges without requiring gusset plates.

Rolled beams are most appropriate for chords and diagonals: they are produced industrially with a high quality standard and are available at low cost and in a wide range of sizes. As a hot rolled product they have a good fatigue resistance. They may easily be hot dip galvanized for corrosion protection.

The open shape of rolled beams facilitates connections. The wide flange beams, and especially the HD 360 and HD 400 shapes, have a high buckling resistance which is particularly required for compression members. Available flange thicknesses of these shapes range from 18 to 125 mm. All rolled sections can be delivered in high quality steel grades with high yield strength, good toughness properties and excellent weldability.

Bridge over the Alzette river in Cruchten, Luxembourg – Transparent truss structure in composite action without gusset plates – S460 rolled steel sections have been used as truss members.



Costa Martina road bridge, Spain – Rolled beam truss girders, continuous over 3 span of 60.6 - 121.2 - 60.6 m. The picture shows the bridge before the erection of the precast slab elements on the upper chords.



11. Footbridges and Cycle Track Bridges



Footbridge over the expressway at Soleuvre, Luxembourg



Pedestrian crossing of Kirchberg, Luxembourg



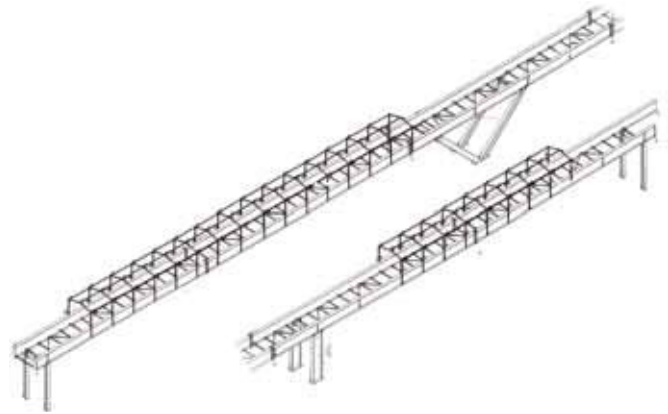
Conceptual design of footbridges and cycle track bridges is often governed by requirements which are not purely functional such as span and intended use. Integration to the environment, alignment to existing footpaths or cycle tracks, arrangement of access ramps, possible adding of a roof are all factors which can exercise a determining influence on the choice of the structure type. Hence the wide range of requirements with respect to design and aesthetics results in a number of possible forms of construction.

The floor may be arranged at the top level of the structure or at lower level if the structure is of the through or half-through type. Main girders may be straight or curved.

Bottom view on the footbridge at Soleuvre, Luxembourg – Sheet piles are used for the abutments.



Footbridge for the visitors of a leisure park in Wavre, Belgium – Through type bridge with thematic enclosure.



Footbridge over the national road at Wasserbillig, Luxembourg

Floor at top level

Most frequently the floor slab is supported by two main girders.

Wooden decks have proved successful with small spacing of girders. Steel cross beams and bracings are then required. A reinforced concrete floor offers the advantages of composite construction if connected structurally to the steel girders. For narrow decks precasting of slab units speeds up construction.

Design and detailing are similar to those for road bridges. Girder dimensions are comparatively smaller and the span range covered with rolled beams is wider.



Bottom view on the twin-girder, composite footbridge at Wasserbillig, Luxembourg



Access footbridge to the building of the Court of Justice of the European Communities, Luxembourg – Architectural design based on lattice girders.

Half-through construction

Half-through cross sections with the floor at bottom level are often used because the shallow construction depth provides the shortest lengths of ramps. Main girders may also act as a parapet.

Cross beams are rigidly connected to main girders for lateral stabilization through U-frame action.

The cross beams carry the floor made of wooden or steel planks, precast concrete units or in-situ concrete cast on permanent formwork. Horizontal bracing is located underneath.

Transport and erection

Main girders, cross beams and bracing are usually transported to site as individual components. Long beams are site spliced.

The bridge may be erected in final position or alternatively be completely assembled next to the final site and then lifted or launched into position in one unit. The last method requires heavier equipment but permits very fast erection with minimal disruption to existing traffic.

Equipment

Footbridges are looked at from both short and long distances. Therefore the design for appearance of equipment, such as parapets, lighting, etc. are particularly important.

Footbridges built to interconnect buildings are mostly of the covered type. A lattice girder form with the roof attached to the top chords is then suitable.

Other construction types

For different reasons other construction types may be used: suspended, cable stayed, truss, arch, etc. For all types the wide range of rolled sections offers a variety of design possibilities.

Conclusion

The use of rolled beams in the construction of footbridges and cycle track bridges offers a number of advantages: simple design, low fabrication costs, fast erection, minimized disruption to existing traffic, attractive forms and colours.



Erection of half-through type structure - Pre-assembled framework including permanent steel shuttering is lifted into position by crane.



Footbridge over the Sûre at Steinheim, Luxembourg

View on the wooden walkway of the half-through bridge with rolled sections in Steinheim, Luxembourg



Bottom view on the stiffening elements of the bridge in Steinheim, Luxembourg



12. Finishing Work at ArcelorMittal Commercial Sections



Cutting of PreCoBeams with the full-automatic oxy-cutting process in the finishing workshop.

12. Finishing Work at ArcelorMittal Commercial Sections



Finishing workshop - Cambering of bridge girders on the press.

The finishing workshop at ArcelorMittal Commercial Sections is equipped to fabricate long lengths, heavy rolled beams, and in particular for operations required in the manufacture of bridge girders. These including sawing, bending about one or both main axes, the welding of shear stud connectors and end



Finishing workshop - Welding of shear stud connectors.

plates, and the drilling of the web and flanges. Longitudinal cutting, notching, machining and welding work can also be carried out.

Surface treatment by shot blast cleaning and metal spraying or the application of partial or full paint systems can also be carried out in the factory.



Automatic surface treatment equipment - Shot blasting and protective coating of beams.

In this way, steel components can be delivered directly from the rolling mill to the site, resulting in reduced costs and improved construction deadlines.

Surface Treatment

In addition to the significant aesthetic function (see chapter Design and Appearance) surface treatment has to provide an effective protection against corrosion.

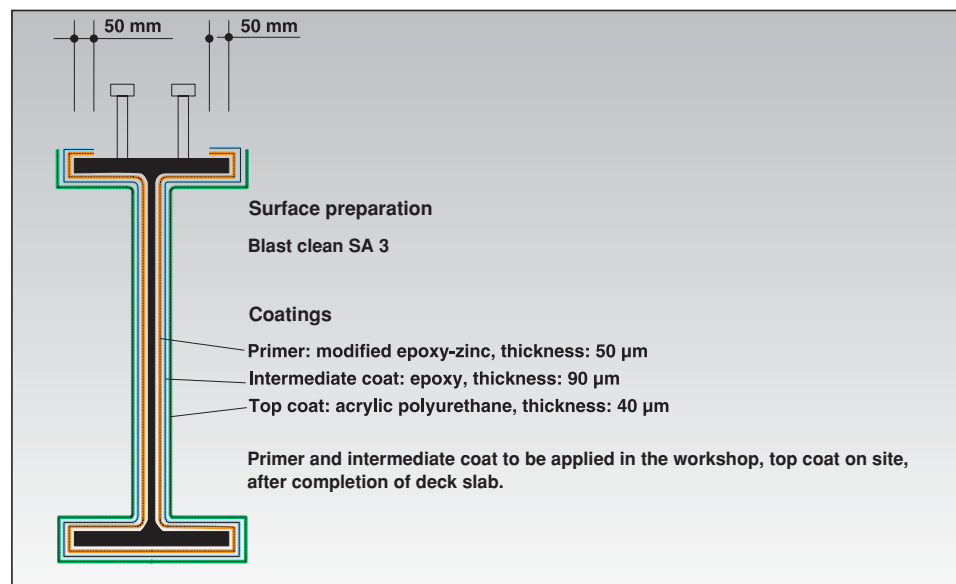
The following are conditions for a durable protection:

- careful surface preparation
- controlled application of the protective coating
- regular inspection during the life of the bridge and immediate repair of any damage.

Over the last few years, much progress has been made with respect to paint formulations, their application, their durability and their environmental friendliness. In general, modern coating systems last for at least 20 years before major maintenance.



Filler beam bridge built over a heavy traffic railway line - High quality coating provides durable protection to lower flanges.



Example of protective treatment for composite decks.

A number of aspects have to be considered for the choice of the appropriate system: type and expected life of the bridge, local climate and other environmental site conditions, constraints relating to maintenance, possibilities of surface preparation and painting, metal spraying or galvanizing at workshop, and feasibility of applying the final coating on site.

Steel components which are encased in concrete do not require coating. However transition zones must be carefully designed.

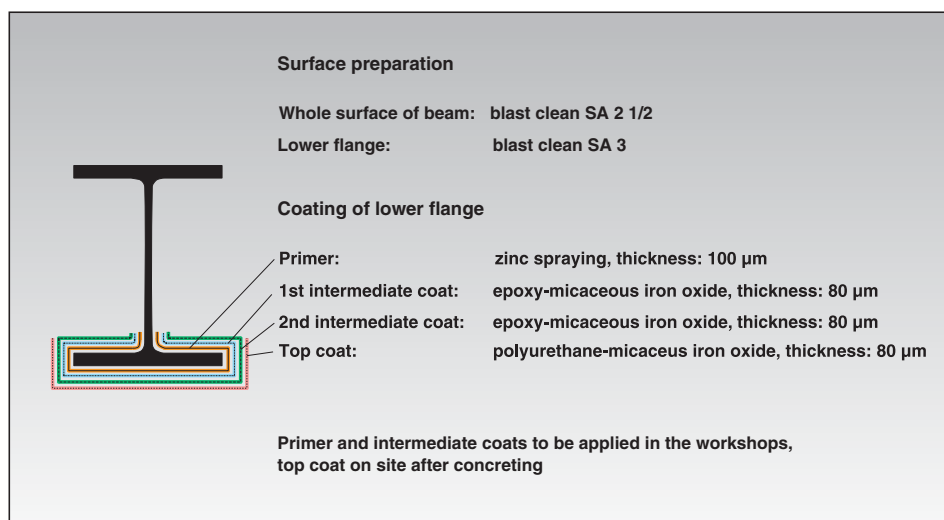
It is recommended to carry out as much of the surface treatment as possible in the controlled environment of a workshop. Usually only the finishing coat is applied after erection on site. Here, rolled beams can offer the advantage of already being coated with the required systems in the rolling mill.

Protective coating systems

The choice of a suitable system and the correct application are essential for effectiveness and durability.

The available protective systems include the following:

- painting
- metal spraying
- hot-dip galvanizing
- galvanizing + painting (duplex system)



Example of protective treatment for filler beam decks.

13. Pre-design Software ACOBRI



ACOBRI (**A**rcelor**M**ittal **C**omposite **B**ridges) is a pre-design software for composite bridges with a superstructure based on rolled sections. ACOBRI applies to road-, railway- and footbridges with single as well as multiple spans. Various alternatives of cross-section types like conventional deck, deck with prefabricated composite beams, box girder deck, concrete-filled box girder and filler-beam deck are included. The pre-design is carried out according to the French, German or Eurocode (EN) regulations. The software is available as French, English and German version.

Please check our website for download and recent updates of our software:

sections.arcelormittal.com

14. Sustainable Bridges with the Use of Rolled Sections

Sustainable bridges with the use of rolled sections

The preservation of natural resources in our industrialized societies has become priority in creation of built environment. As a result, construction concepts have to comply with changing economical parameters like the incorporation of life cycle analyses in the design of structures as well as with technological changes in considering sustainability goals in respect to the environment and society.

These sustainability goals are in nature:

- ecological,
- economical,
- socio-cultural,
- technical oriented,
- process oriented.

They are interdependent as well as ambivalent, providing a coherent response to complex questions and ensuring future generations a pleasant environment.

Bridges are of vital importance to the transport infrastructure of societies. Growth in traffic density during recent decades has been tremendous. As a consequence, numerous new roads and railway lines were built or are planned to be realized in the near future. Meanwhile,

existing bridges must carry the increased traffic; considering all bridges, short span bridges are the most frequent category. Therein, the use of rolled sections can play a significant role.

Sustainable bridges using rolled steel sections provide the opportunity to give an answer to the infrastructural demand while being fully consistent with the various aspects of sustainability goals.

Ecological aspects of sustainability

The main ecological goals aim at using construction materials that are safe from health and environmental points of view, reducing waste when dismantling the structure at the end of their service life, and at preserving as best possible the energy content in the construction materials, thus maintaining their ideal efficiency. Here, structural steels offer high material efficiency and rolled sections constitute the most recycled construction material in the world. In the modern electric arc furnace (EAF) route, steel is produced using 100% scrap as a raw material (upcycling). In addition, EAF technology allows for significant reductions of noise, particle and CO₂-emissions as well as water and primary energy consumption in the production mills.

Bridges using rolled sections are maintenance-friendly structures, easy in deconstruction and excellent to preserve the resources for recycling at the end-of-life. The recovery rate of rolled sections in bridges is 99%. Also, steel elements can be re-used after dismantling. Due to their low weight, the possibility to use detachable connections and fast erection schemes e.g. mobile bridge designs have been developed with the use of rolled beams.

Economical aspects of sustainability

Besides being interested in the reduction of investment costs, investors are also concerned about the optimization of operational costs and the achievement of the longest possible service life in combination with high flexibility in use of the structure.

Rolled sections in bridge construction allow architects and designers to easily fulfill the requirements of investors by combining high quality, functionality, aesthetics, low weight and short construction times.

Slender superstructures can be designed which decrease construction height and earthworks leading to a further decrease of material, fabrication, transport and construction costs.



Reconstruction of bridge over the Nahe near Bad Münster am Stein, Germany – This bridge is located in a nature reserve. A composite deck was constructed on the existing piers.

Short construction times and therefore reduced traffic disturbance save user costs during construction, enabling public savings to be achieved. Tenders including the life cycle costs prove the competitiveness and sustainability of composite construction for bridges with short and medium spans.

In addition to economic constructional costs, steel and composite bridges are also operationally economical. They are easy to maintain, because the structural components are readily accessible for inspection and maintenance work. Inspecting composite bridges is simple and reliable.

Bridges using rolled sections can be repaired. Composite bridges are a flexible and low cost method in adapting to changes in requirements e.g. the widening of traffic lanes or the strengthening of the structure.

Socio-cultural aspects of sustainability

Bridge design has also to take into account aesthetic demands with the social expectations of its surrounding environment, either by design of an architecturally uniform work or structures which do not over-dominate visually. Bridges with the use of rolled steel

sections lead to transparent and lean structures combined with robustness and safety. Local inhabitants and their social environment remain clean in uncontaminated surroundings as steel in structures does not release any harmful substances into the environment.

Technical aspects of sustainability

Composite bridges with rolled beams have the advantage of being able to resist high level utilization and are adaptable to changes in use. These robust construction solutions are capable of coping well with variations in use during service life without damage or loss of functionality. Especially for the refurbishment of bridges, intelligent solutions are required. On the one hand the public economy has to be satisfied to a certain extent; on the other hand technical, economic and political boundaries have to be respected. In this regard, composite construction is providing the potential with the possibility to use cost-effective construction techniques and advanced construction procedures providing adaptability of the available bridge systems.

Process aspects of sustainability

Steel construction offers many advantages through its flexibility, lightness and cost effectiveness. In composite construction for short and medium span bridges, rolled beams are used as primary bearing elements. They are industrially produced to a high quality, offer good availability in a full range of sizes and steel grades, including the high strength grades (e.g. Hystar). With long lengths possible the end product is accordingly delivered to site ready for erection. Quality control has already been carried out at the producing rolling mill. Smaller construction sites and plant equipment are therefore needed whilst minimal noise and dust disturbance on site are characteristics for steel construction.

The bridge solutions using hot rolled sections can reduce erection times. Hence, cost for traffic control measures are saved as well as accident potential is reduced. These bridges are designed to be constructed without essential interference to the traffic under the bridge as well as to incorporate minimized traffic disturbance throughout their maintenance.

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Construction

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