SIMPLE AND EFFECTIVE SOLUTION FOR MEDIUM SPAN RAILWAY BRIDGE

FILLER BEAM COMPOSITE DECKS – REVIEW AND EUROPEAN EXPERIENCE

RICCARDO ZANON

TONI DEMARCO

BIOGRAPHY

Riccardo Zanon, S.E., MBA, is Head of Technical Sales for Eurostructures Beam Finishing Centre in Luxembourg, within ArcelorMittal Europe – Sections & Merchant Bars. Previously he held positions in the R&D Centre and Technical Advisory Department at ArcelorMittal Europe. He is a graduate of the Technische Universität Dresden (Germany) and of the Sacred Heart J. Welch University (Connecticut, US).

Toni Demarco, S.E., is Head of Eurostructures Beam Finishing Centre in Luxembourg, within ArcelorMittal Europe – Sections & Merchant Bars. Previously he held positions in the R&D Centre, Sales Manager for Sheet Piles, and Technical Advisory Department for Sections and Merchant Bars at ArcelorMittal Europe. He is a graduate of the Universität Karlsruhe (Germany).

SUMMARY

In the framework of a politic of large structural investment plan, Europe has been developing its infrastructure network over the past decades to allow for a better integration amongst countries. Whereas for the roadway network the efforts have been concentrated in Eastern Europe, the public rail network of Western and Central Europe is undergoing a vast campaign of renewal and modernization.

When it comes to railway infrastructure, the classical european steel-concrete solution is the filler beam deck which is well-known and widely used for small and medium span bridges. According some estimations this structural typology corresponds to 10% up to 25% of the existing bridge stock depending on the country.

On one hand their use has decreased for simple structures faced to prestressed concrete decks, but on the other hand they are now implemented for a wider range of spans and train speeds as well as for integral bridges. The paper will focus on the structural concept, the design, the execution and the assessment of this bridge deck typology.

Simple and effective solution for medium span railway bridges Filler beam composite decks – review and European experience

Figure 1: Left: view of rolled section at the rolling mill; Right: view of steel-concrete composite deck with rolled girders – East LGV line Paris- Strasbourg, RN3 overpass at Pomponne

1. INTRODUCTION

1.1 Concept and historical development

A filler beam deck is composed of rolled sections, closely spaced and encased with reinforced concrete. In the longitudinal direction the steel girders act compositely with the concrete and carry loads along the bridge span; whereas in the transverse direction, rebar ensures the transverse bending resistance of the reinforced concrete. Permanent formwork are foreseen between the lower flanges of the beams. Corrosion protection is needed only on the bottom flanges of the sections, the rest of the steelwork being encased in concrete.

The first formal statement of this new structural typology goes back to Mr. Descubes, chief engineer from the French railways SNCF, in the 19th century [1], whereas it had been already widely used in France and Germany since years. The main asset of this solution was its ability to overcome the disadvantages of steel structures of the time (maintenance difficulties, repair and replacement of connecting elements – in particular rivets and clouts, renewal of corrosion protection) for the small span decks. The first projects used rails or H-beams, stiffened with transversal struts, supporting a small masonry vault. This system was then filled out with non-structural mortar which was supporting the railway line.

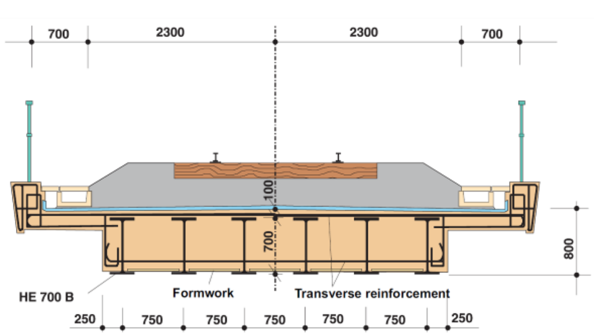


Figure 2: Cross section of a typical railway bridge using filler beam deck [3].

Figure 3: First filler beam bridge with 1m tall beam (HEB1000), Fentange, Germany 1917.

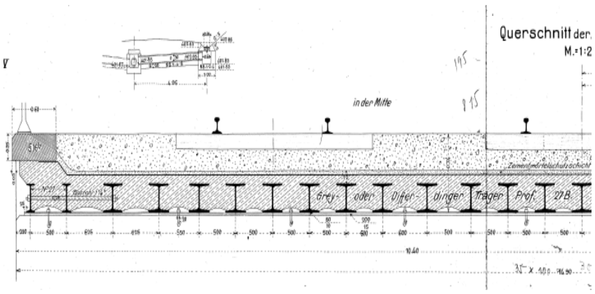


Figure 4: Cross-section still in use: line Basel-Olten, km 24.216, 1902, Switzerland.

For several decades the beams were designed as non-composite in the longitudinal direction. But then already in the first half of the 20th century the calculation developed to a composite cross-section design for the longitudinal direction [1].

1.2 Field of application

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 evenwhere the service conditions have changed.

Filler beam construction is today mainly used:

- for decks with restricted construction depth;
- for bridges crossing roads as 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.

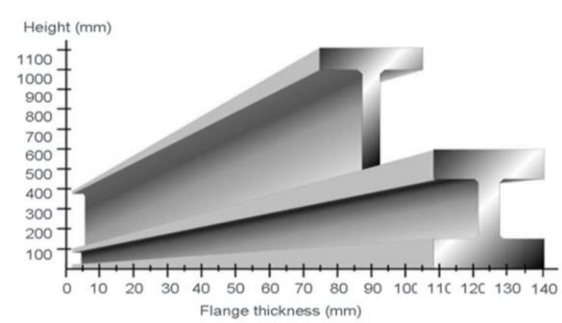
The span covered by filler beam decks range (figures in brackets apply for continuous multiple span bridges):

- up to 40 (50) meters for road bridges;
- up to 30 (35) meters for railway bridges.

1.3 Availability of strucural shapes

Major structural component of this typology are H-structural shapes, first out of Iron and then out of Modern Steel. Rolled structural shapes (L, I, H, U) were developed at the end of the 19th century, answering the need to simplify shapes built up from plates assembled together by rivets. The advantages in terms of weight savings, fabrication simplification and cost reduction were integral to the acceptance of rolled shapes in every field. Today, the geometric range of available H structural shapes is extensive (beam height 80…1150mm, flange width 50…450mm, flange thickness 4…140mm) with a well-established presence of production sites around the world [5], [6], making structural shapes a well-known standard products known by Engineers and Steel Fabricators.

In addition to expansion of geometric properties, the development of optimized rolling procedures occurred over several decades. Since the 1990, thermo-mechanical rolling has become a standard for the most advanced plants in Western Europe. Proper to this In order to enhance the benefits of thermomechanical rolling, the quenching and self-tempering process (QST) was developed specifically for sections with thick flanges. Implementing this innovative procedure, made it possible to economically obtain high steel strengths (up to 485MPa) for heavy sections without the costly addition of alloying elements [8], [9].



Grade	Yield Point, min. ksi	Yield Point, min. [MPa]	Tensile Strength, min. ksi	Tensile Strength, min. [MPa]	Elongation, min 8 in. [200 mm], %	Elongation, min 2 in. [50 mm], %
50 [345]	50	[345]	65	[450]	18	21
60 [415]	60	[415]	75	[520]	16	18
65 [450]	65	[450]	80	[550]	15	17
70 [485]	70	[485]	90	[620]	14	16

Figure 5: Availability of Structural shapes [15].

2. DESIGN

2.1 European normative approach

Filler Beam Decks are designed in Europe according EN1994-2 : 2005 [18], dedicated to steel-concrete composite bridges. A chapter for the design of the cross-section is the 6.3, whereas other constructive and complementary rules are in chapter 5 and chapter 7. Nonetheless other standard published by National Railway Authorithies are interacting with the Eurocode and have to be considered.

The new version of the French standard „IN0035, Livret 2.32“ [22] contains only rules about the steel choice, fabrication and corrosion protection, whereas the design is done according Eurocode completed by the national Annexes. The German standard „DB Ril 804“ [23] includes some complementary rules but which are in general simplifying the design. It has to be underlined that a a recent work in collaboration between the steel industry and the railway authorithies has published a whole book of solutions which are already validated. The Italian technical specification [24] also contains several tables of pre-engineered solutions, having said that in this country mainly simply supported decks have been built. The solutions have been designed at the elastic limit state since the deflection limit is governing the design for the configurations which have been studied.

2.2 Cross-section design

The calculation allows only for rolled sections (or eventually with welded sections with the same geometric dimensions). A skewness up to 30° is allowed, whereas for or beams with curvature in plan a complex model shall be adopted.

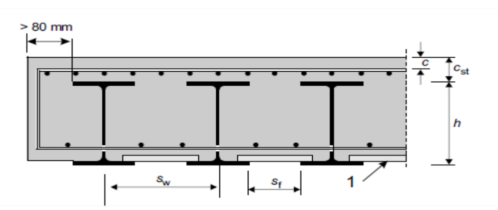


Figure 6: Geometric definition of a filler beam bridge deck [18].

There are several geometric restrictions which have to be regarded:

- the nominal depth h of the steel beams complies with: 210 mm $\leq h \leq$ 1100 mm;
- the spacing s_w of webs of the steel beams should not exceed the lesser of h/3 + 600 mm and 750 mm, where h is the nominal depth of the steel beams in mm;
- the concrete cover c_{st} above the steel beams satisfies the conditions:
  $c_{st} \geq 70$ mm, $c_{st} \leq 150$ mm, $c_{st} \leq h/3$, $c_{st} \leq x_{pl} - t_f$
  where x_{pl} is the distance between the plastic neutral axis for sagging bending and the extreme fibre of the concrete in compression, and t_f is the thickness of the steel flange;
- the concrete cover to the side of an encased steel flange is not less than 80 mm;
- the clear distance sf between the upper flanges of the steel beams is not less than 150 mm, so as to allow pouring and compaction of concrete;
- the soffit of the lower flange of the steel beams is not encased;
- a bottom layer of transverse reinforcement passes through the webs of the steel beams, and is anchored beyond the end steel beams, and at each end of each bar, so as to develop its yield strength; their diameter is not less than 16mm and their spacing is not more than 300 mm;
- normal-density concrete is used;
- the surface of the steel beams should be descaled. The whole lower flange of the steel beams should be protected against corrosion;
- for road and railway bridges the holes in the webs of the steel section should be drilled.

The scope of these rules was developed to adapt the typology to a cross-section under positive sagging moment:

- lower flange shall be outside the concrete, so that the cracking limitation on the lower side will not be governing the design.
- upper concrete coverage is limited so to allow a full use of the steel flange before concrete explosion on the upper fiber
- beam spacing is limited so to strongly limit the transversal bending moment overtaken by the reinforce concrete, so not to reduce the capacity in the longitudinal direction.

It is important to stress that under these conditions the cross-section can be designed composite without the need of justifying the shear-connection. The steel-concrete is ensured by the contact surface as well as the transversal rebars creating concrete dowels in correspondance of the holes in the web.

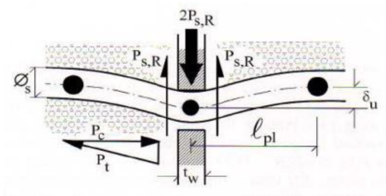
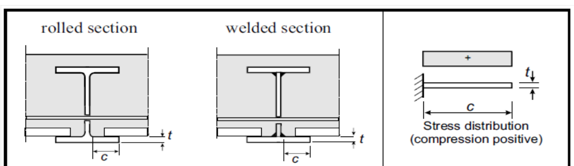


Figure 7: Mechanical work of a bar in concrete [10]

Under the condition that the cross-section respect the limit for the class 1 or 2 concerning the lower flange (which is the standard case), the verification under bending moment is done at the plastic limit state taking into account the steelwork, the concrete and the rebars in tension. Conversely the shear action is attributed only to the steel beams; anyway in this structural typology this never becomes a design issue. In transversal direction, the deck is calculated as a traditional reinforced concrete plate. The cracking limitation is done as if the non-participating formwork was not there, whereas it can be taken into account concerning the reinforcement coverage.



Class	Type	Limit max (c/t)	
1	Rolled or welded	$c/t \le 9\varepsilon$	$\varepsilon = \sqrt{\frac{235}{f_y}}$ with f_y in N/mm^2
2		$c/t \le 14\varepsilon$	
3		$c/t \le 20\varepsilon$	

Figure 8: Cross-section classification for filler beams [18]

In the final phase there is no danger of instability as the steelwork is embedded in the concrete. During the construction phase on the contrary the steelwork is overtaking all the self-weight including the fresh concrete. Therefore the steel beams have to be verified and sufficient anti-LTB devices are provided in terms of temporary bracings and struts. Some pictures of the most common devices are showed in the chapter dedicated to the execution phase (see Figure 17). Concerning the serviceability limit state, all the usual stress limitation verifications are lead as for a normal composite section. For deformability checked one part of the cracked concrete is taken into account (the inertia of the concrete is calculated as the average of the non-cracked cross-section and the inertia of the full cross-section).

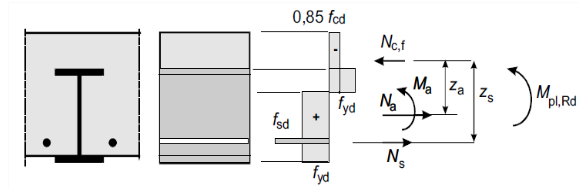


Figure 9: Calculation of sagging moment resistance [18]

Design according fatigue limit state is done as usual, having noted that this is never governing the dimensioning of the beams. In fact there is no major fatigue detail so in the old codes it was stated that fatigue verification could be skipped provided that holes were drilled (not punched) and deburbed, and continuity joints, if any, are verified (in fact they can be located in zone of low stress use).

2.3 Optimal choice of the steel grade

In Europe, rolled as well as plated girders for bridges are usually constructed in steel grade S355 [14] (comparable to Grade 50 in US). This grade is quite common, eventually available on stock, and implies well known and mastered welding procedures. Using plates in higher steel strength is not common for small to medium span bridges, as the quantities are not sufficient to order the plates directly at the mill (since the tonnages is splitted on a wide range of thicknesses, and in particular for the small thicknesses).

When it comes to rolled girders in S460 (comparable to Grade 65), this option is well established in the European practice and is economical advantageous, as the high strength can lead to weight savings in the design of the structural system. In addition, when high-strength sections are produced using a quenching and self tempering process, the members' low-carbon content results in improved weldability of the material. As a result of the benefits of weight savings and simplifed fabrication, rolled girders in high steel strength have become a solution of choice for standard small span bridges [5]. For road bridges rolled girders in high strength steel are becoming a standard. Conversely for railway bridges the design is often governed by the deformability checks so that the use of high strength steel is not common.

3. EXECUTION

3.1 Steel fabrication

In Europe major steel plants for rolled beams have integrated beam centers which can take in charge basic finishing such as cut-and-drill, camber, welding and finishing of heavy structural shapes as a service to the customer. This appears to be very important in particular for heavy shapes with long lengths, as this cut down logistic costs and permits to develop specific machinery and know-how in fabricating this heavy section.

Steel girders for these decks are therefore produced and fabricated directly at the steel plant. As it comes of railway bridge application, the steel is produced on a specific order in the steel grade specific to the relative railway authorities and then controlled and certified. From the normative point of view, the harmonized European standard for structural steel (EN10025 : 2005 [19]) is completed by national recommendations ([21], [22], [23]) which may specify additional testing such as Ultrasonic testing to verify he internal soundness, stricter surface requirements (less imperfections or mechanical grinding) or stricter chemical composition (in particular to avoid the risk of fragility or inclusions).

Figure 10: Rolling of structural shapes out of Beam Blanks

Fabrication is executed in accordance to the European standard for steel execution (EN1090-2 : 2012 [20]), in the usual case according to the Execution Class 3 (which is the second most severe after the 4, applicable for special structures and major bridgeworks). The first step is to curve the structural shape in cold condition to include the wished cambering form to compensate deformations under self-weight.

Figure 11: Curving of tall beams in full length by means of a gag press in cold condition

After being cut-to-length, holes are drilled in the web to install stabilization systems and transverse reinforcement. In average there are between 5 and 10 holes per meter of beam with diameters varying between 27 and 50mm according to the needs. The holes and the cut edges are grinded to avoid any mechanical crack initiation as according to [20].

Figure 12: Cutting to exact length by saw blade, automatic drilling in the web and in the flanges

Corrosion protection is applied on the basis of the international standard ISO EN 12944 [24] but completed also by national standards (e.g. [21], [22], [23]) which specify the system. Steel is shot-blasted prior to fabrication so to allow for surface controls and a proper fabrication. Afterwards only the exposed lower flange and the adjacent part of the web is treated and prepared to achieve a high steel rugosity class Sa3. The first layer is either a primer rich of zinc or a hot zinc projection (also known as cold-galvanizing) for a thickness between 80 and 120 micron depending on the system. On this most important layer a thin layer on the edges as well as to close the porosity is applied. Afterwards several layers of epoxy organic coating, a top coating (polyurethane) finish the system.

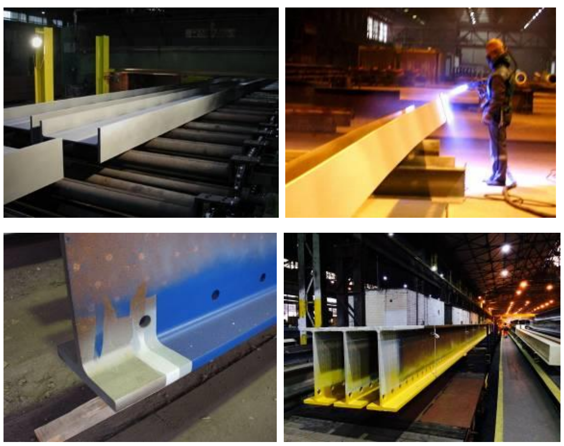


Figure 13: Automatic shot-blasting and manual application of metallization and organic coating layers

3.2 Transportation

Fully finished beams are transported preferably by railroad in order to decrease environmental impact and freight costs. There is an important know-how to tranport successfully long products on the European railway network. Whereas 24m is still standard length, up to 32-33m does not represent major issues as the beams can still fit on one standard wagon accompanied by an empty shock wagon on top and on queue. The topic becomes more challenging as the 35meter length is exceeded, because the beams have to stand on two different wagons. The record was set in 2013 by trasporting filler beam girders with lengths up to 60.6m.

Truck deliveries are also quite common and have the main advantage to avoid maintenance between the railway terminal and the construction site. Longest filler beam girders deliveries have been achieved in 2011 with 42.5m.

Figure 14: Exceptional rail transport of 54.16m already coupled in the workshop, Railway Bridge at Boulevard Ney a Paris, 2000, France

Figure 15: Exceptional rail transport of 39.7m beams with curvature about weak axis with a radius of 354m, Roadway Bridge RD257 in Arles, 2014, France

Figure 16: Exceptional road transport of 42.5m beams, roadway Bridge B6N in Magdeburg, 2011, Germany.

Figure 17: Fixing of bracing devices before erection

3.3 Erection and stabilization

Once beams are delivered on the construction site, it is important to stabilize them by means of temporary elements such as struts and cross bracings. This is actually the only phase where this robust deck typology can encur some risks of instability, so it is very important not to skip this verification to avoid catastrophic effects on the constructions site.

Steel elements are typically erected by crane in packages of several beams lifted together directly into their final position on the bearings. Lower reinforcement layer may be installed before erection, whereas the standard practice is to install after.

After installing some distancing elements amongst the beam lines, concrete is poured on the deck in several steps (at least 3: firstly just about 10cm, afterwards up to the upper flange, and finally to the final level). Repositioning of the deck after concreting may be necessary for the correct introduction of load onto supports.

Figure 18: Lifting of beam packages on bridge supports

Figure 19: Filler beam deck concreting

Figure 20: Filler beam deck during construction phase

3.4 Jobsite splice – Bolted connection

In case beams have to be spliced on the jobsite to achieve a continuous girder, the easiest and cheapest solution is usually to use cover plates to be bolted on the flanges and on the web of the structural shape. Other bolted connections such as header plates are not suitable for this kind of application and are not recommended.

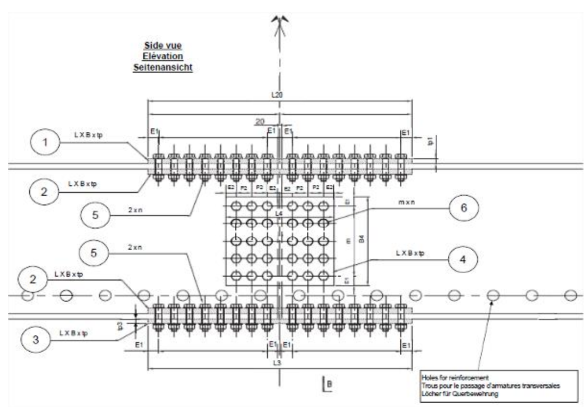


Figure 21: Example of a bolted splice with cover plates

When designing such detail, first of all it is important to check the constructive details because these plates have to fit in the system of the transversal and longitudinal reinforcement, let the place to support the formwork in transversal direction, and of course allow for some tolerances to be erected on the jobsite condition. In particular with the use of tall beams with long lengths, the fitting in on the construction site may require some time.

Figure 22: Installing of filler beam girder with bolted connection splice

Bolted connections subjected to fatigue have to be designed as slip-resistant with high strength preloaded bolts (8.8 or 10.9 class) [17]. Specific attention has to be concerned to the friction surface, as the execution is linked with the splip factor which has been taken in the design note. There are 6 different options which are possible in the future prEN1090-2, nevertheless only two are relevant for slip-resistant bolted connections (A or B, correspondent to a slip factor 0.5 or 0.4) [20].

Surface treatment	Class [a]	Slip factor μ
Surfaces blasted with shot or grit with loose rust removed, not pitted.	A	0,50
Surfaces hot dip galvanized to EN ISO 1461 and flash (sweep) blasted [b] and with alkali-zinc silicate paint with a nominal thickness of 40 μm to 80 μm.	B	0,40
Surfaces blasted with shot or grit: a) coated with alkali-zinc silicate paint with a nominal thickness of 40 μm to 80 μm; b) thermally sprayed with aluminium or zinc or a combination of both to a nominal thickness not exceeding 80 μm.	B	0,40
Surfaces hot dip galvanized to EN ISO 1461 and flash (sweep) blasted (or equivalent abrasion method) [b]	C	0,35
Surfaces cleaned by wire-brushing or flame cleaning, with loose rust removed	C	0,30
Surfaces as rolled	D	0,20
[a] Classes as given in G.6. [b] Unless alternative equivalent abrasion process capability can be demonstrated, flash (sweep) blasting of hot dip galvanized surfaces shall be carried out according to the procedures and conditions set out in EN 15773 [13].		

Table 1: Surface treatment classes in function of the design slip factor [20]

3.5 Jobsite splice – Welded connection

The other option is of course to realize the splice by means of a welded splice. The choice of this option instead of the previous one is typically linked with the habit of the administration and the design office, as the two possibilities have been successfully implemeted for decades both for roadway and railway bridges. Esthethic in this case is not a topic as the splice is embedded in the concrete and only the lower flange is visible.

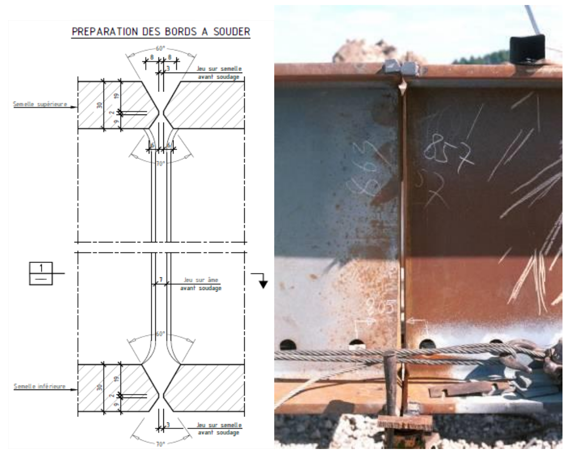


Figure 23: Weld bevel preparation for a welded splice on the construction site.

When welding together structural shape particular attention has to be dedicated to the k-zone where flange and web comes together [2]. In general the thicknesses of the flanges are not more than 40…50mm (1.5…2 inches) so the coping hole is not foreseen. Full penetration welds are foreseen with access from both side and root in the middle or 2/3 – 1/3 in the material thickness. Welding is then checked 100% at Ultrasonic testing and Magnetoscopic testing.

As a general case, the welded option is more costly than the bolted splice version for this bridge typology. Conversely as a major advantage, there are more geometric tolerances if the splice on the construction site can be done welded. Nevertheless for both cases a workshop pre-installation is usually done to ensure the geometrical fitting of the fabricated steelwork.

4. SPECIAL APPLICATIONS

4.1 Filler beams within integral bridges

As a general trend through the bridge construction engineering, small and medium decks are more and more conceived as integral to the piers and / or abutments in order to achieve structural and economical advantages [10], [7].

Figure 24: Example of Filler Beam with monolithic connection to the intermediate pier [16]

A brilliant example with filler beam deck is the the reconstruction of the railway bridge Großenhainer Strasse in Dresden [16]. The reconstruction has been realised by the company SSF Ingenieure AG as a modern, semi-integral three-span bridge (Span: 19,40m + 22,10m + 19,40m = 60,90m) with two double-tracked superstructures (Total width: 21,20m) in a crossing angle of about 65°. Further selection criteria were the erection of the bridge in a constricted area and minimal disturbances to traffic. The combination of the advantages of the frame structure with those of the filler beam structure allows the realisation of a low-deformation, robust and low-maintenance superstructure with low noise emission.

4.2 Filler beams as transversal deck

Another common application for filler beam is as transversal deck for Half-through bridges. The lateral girders, usually executed as plated girders with a height between 2m and 5m, are connected through main cross girders (moment-resisting connection, therefore ensuring the U-frame action) and secondary cross girders (pinned connection, just ensuring load transfer from the deck to the lateral girders).

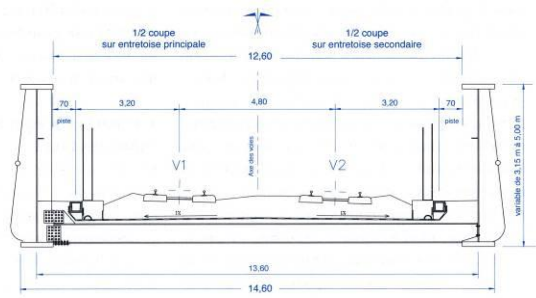


Figure 25: Typical example of cross-section for a LGV Half-through deck [11]

The filler beam technology ensures a very slender but robust deck, stiffness to the lateral girder in the construction and in the final phase.In the design of the deck particular attention is dedicated to the limitation of cracking in bridge longitudinal direction. In fact due to the bridge global bending action, the filler beam deck can work under transversal tension, which is quite severe for the filler beam concept. For this reason the reinforcement ratio is quite important and two series of web openings with consequent diameter has to be foreseen.

Also in this case the rolled sections are ordered directly at the steel mill, where after rolling they are fabricated and provided with finishing, coating and beam end preparation (chamfering for welded connection or holes for bolted connection) for direct delivery to the construction site. Filler beams as transversal decks are used not only with lateral plated girders but also for bow-strings.

Figure 26: Cross girders for Half-through decks with lateral girders

5. ASSESSMENT

5.1 Advantages of filler beam decks

The main advantages of these construction typologies are the following [10], [8]:

- **Slenderness**: the high-load bearing capacity of the encased steel beams permits extremely high slenderness ratios (span / construction height) compared to other technologies;
- **Reduced traffic disturbance**: structural steel is self-supporting and host place for formworks. Linked with the previous advantage, it makes this typology a preferred solution for railway/roadway overpasses;
- **Robustness**: thanks to compact deck solution, lack of delicate prestressing devices, structural continuity over the whole bridge length;
- **Durability**: structural steel is very well protected against corrosion, structural concrete is used during the lifetime at a relatively low utilization ratio. Thanks to the minimal amount of welding, fatigue is not an issue.

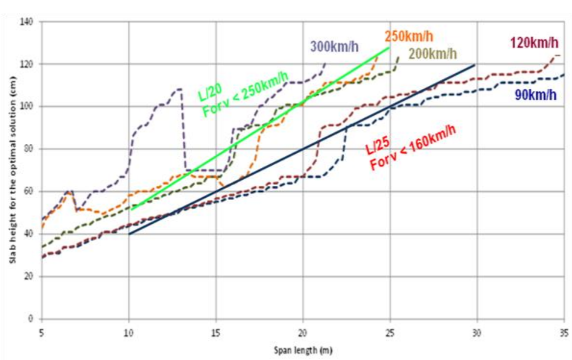


Figure 27: Slenderness ratio of filler beam decks [16]

5.4 Outlook of railway infrastructure in EU

Requirements on the European infrastructure for passenger and goods traffic have increased due to the stepwise extension of the European Union. Bridges are part of that infrastructure. Adaption are necessary in the new EU-member states (Poland, Romania, Czech Republic) as well as in old ones (UK, Germany, France, Italy, Spain) with new main arteries. Experts for instance predict an increase of the traffic capacity in the public freight transportation of ca. 70 percent until the year 2025 [12]. The maintenance of the existent constructions has to be ensured in addition to the extension of the railway infrastructure. The maintenance is challenged by the increase of the traffic and the ageing of the existing bridges.

Rank	Country	Total (km)
1	Germany	43,468
2	France	29,640
3	Italy	24,179
4	Romania	22,298
5	Poland	19,627
6	United Kingdom	17,732
7	Spain	15,947
8	Sweden	12,821
9	Czech Republic	9,487
10	Hungary	7,942

Table 2: Rank of national railway network within EU by extension [12]

5.2 Experience and outlook in Germany

Analysis of the heritage of German Railways [13] shows that, of the roughly 31000 existing structures, more than a quarter are filler beam decks. This means that traveling on the German railway network for an hour with a speed of 160 km / h, on average the train rolls 35 decks of this type. The same situation is found in several countries in continental Europe, giving solid foundation to the assumption that the number of filler beam decks in service today on the European rail network exceeds by far 10,000 units.

The main reason for this success is the reliability and robustness of the structural typology: with an average service age of 88 years, it represents the most durable deck typology available (the average lifetime of railway decks is about 60 years). Even more remarkable, a consistent part of these steel beams are nowadays in service for more than 120 years without major issues.

5.2 Experience and outlook in France

With several other countries, France has been a pioneer in the railway technology, particularly concerning the development of modern high-speed train technology. At today status, its network ranks 5th at worldwide level in term of its extension ([12]). At European level, it ranks at the second place after Spain, but considering its technical development, its connection to various countries, and its position at the crossroad of central Europe it is recognized as the European leader of the sector. The most recent milestones for the development of the French railway network are the four following projects (see Figure 1, [16]):

LGV East – European, 2nd phase: foreseen to be in service in 2016 (9 years after the second phase), it constitutes about 122 km of new railway line between Metz and Strasbourg. It permits to reduce the travel time between Paris and Strasbourg of about 30 minutes.

LGV South European Atlantique: foreseen to be in service in 2017, it constitutes about 342 km of new railway line between Tours and Bordeaux. It is the prolongation of the high-speed railway line Paris – Tours, finished in 1990.

LGV Bretagne-Pays de la Loire: foreseen to be in service in 2017, it constitutes about 211 km of new railway line between Le Mans and Rennes. It is the prolongation of the high-speed railway line Paris – Le Mans.

Contournement de Nîmes et de Montpellier: foreseen to be in service in 2017, it constitutes about 80 km of new railway line between Arles et Montpellier. It is the prolongation of the high-speed railway line Paris - Avignon.

On this new railway line a significant amount of new decks has been realized with the filler beam deck technology. Most interesting is to notice that the usual field of application has been extended to continuous decks up to 31m span.

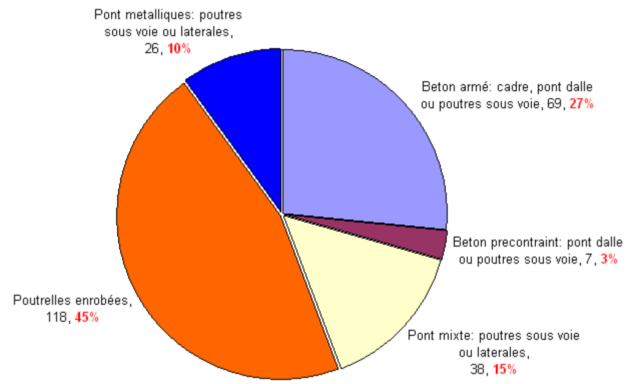


Figure 28: Market shares of different decks for new railway bridges built 2000 - 2006 [16]

6. CONCLUSIONS

This paper gives an overview about the filler beam deck technology for bridges, which is a traditional construction method in Europe since over a century but has proven his resilience and is still widely used. Even without marking major technological innovations, the practice has undergone a significant evolution over the past decades and has enhanced the competitiveness of steel construction for small and medium span bridges.

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8. LITERATURE

[1] Bastien, H., Les ponts métalliques et les ponts à poutrelles enrobées de béton des chemins de fer français: quelques tendances, IABSE publications, 1938.

[2] D. K. Miller, The Challenge of Welding Jumbo Shapes, Welding Innovation, Vol. 10, No. 1, 1993.

[3] ProfilArbed, Design of Filler Beam Deck Railway Bridges, UIC, 1999.

[4] Bouchard S., Axmann G., The Steel of Choice, Structural Engineer, 2000.

[5] Hever M., Schröter F., Modern Steel – High Performance Material for High Performance Bridges, 5th International Symposium on Steel Bridges, Barcelona, 2003.

[6] Axmann G., Steel Going Strong, Modern Steel Construction, 2003.

[7] G Sedlacek, B Hoffmeister, H Trumpf - Composite bridge design for small and medium spans - Final Report European commission Technical steel report, EUR20583, 2003.

[8] Weber L., Histar High Performance Hot-Rolled Beams, Advanced Materials for Construction of Bridges, Buildings, and Other Structures III, Engineering Conferences International, 2003.

[9] J. Hoffmann, B. Donnay, Thermo-Mechanical Control processing rolling applications in Sections, Bars and Rails, Profilarbed Recherches, 2004.

[10] Schmitt Stumpf Frühauf und Partner - Effiziente Brücken in Verbund (Efficient composite bridges), Forschungsvorhaben P 629 – FOSTA, 2005.

[11] O. Hechler, LG. Cajot, PO. Martin, A. Bureau, Efficient and economic design of composite bridges with small and medium spans, ECCS International Symposium of Steel Bridges, 2008.

[12] K Barrow, RFF maps out a high-speed future, International Railway Journal 2009.

[13] J. Müller, Brückenbestand bei der Deutschen Bahn – Bewertung und Ausblick, Preco+ Seminar, Düsseldorf, 24.09.2012.

[14] R. Zanon, W. Ochojski, O. Hechler, Paweł Klimaszewki, W. Lorenc, Road bridges WD7-WD8 on Route Sucharskiego, Gdansk, Poland - Prefabricated composite beams with high-strength hot rolled sections, Technical Report, IABSE Structural Engineering International (SEI), 2 – 2014.

[15] S. Finnigan, B. Charnish, R. Chmielowski, Steel and the Skyscraper city – A study on the influence of Steel in the design of Tall buildings, CTBUH Conference, New York 2015.

[16] R. Zanon, T. Demarco, M. Sommavilla, New High-Speed railway lines in France – Development of Filler Beam Decks typology, Proceedings of CTA Conference, 2015.

[17] EN 1993-1-8 : 2005; Design of Steel structures – Design of Joints.

[18] EN1994-2 : 2006; Design of composite steel and concrete structures – General rules for bridges.

[19] EN10025 : 2005; Hot rolled products of structural steel.

[20] EN1090-2 : 2012; Execution of steel structures and aluminium structures - Technical requirements for steel structures.

[21] IN0035 – CPC2.32 Execution des ponts et charpentes métalliques et mixtes, 2002.

[22] DB Ril 804: Eisenbahnbrücken und sonstige Ingenieurbauwerke planen, bauen und instand halten, 2003.

[23] RFI DTC INC PO SP IFS 004 A, Specifica tecnica per la progettazione e l’esecuzione di impalcati ferroviari a travi in ferro a doppio T incorporate nel calcestruzzo, 2011.

[24] ISO EN 12944: Corrosion protection of structural steelwork by protective paint systems, 2007.