Snabba brobyten och brobyggnationer

SBUF-projekt
Rapport nr: 12691

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Summary

This SBUF-project consists in a literature survey with the focus on efficient bridge construction and innovative techniques that can be applied to facilitate a bridge project. The main focus has been to explore bridge projects in urban environment or projects where the work areas were cramped.

During the course of this project interviews have been conducted with entrepreneurs and authorities. Study visits have also been organised apart from the literature survey in order to fulfil the goals of the project.

In USA for instance, a vast on-going program called Accelerated Bridge Construction (ABC) recommends the use of prefabricated elements or whole bridges to speed up the construction process for bridges in order to reduce time and save money. In particular, the reduction of the on-site construction time presents several economic, social and environmental benefits, as described in the first part of the report. The second part has been organised to present some of the techniques on the market concerning prefabricated bridge elements that have the potential to accelerate bridge construction.

The third part of the report addresses the installation of prefabricated elements and the fourth part methods and examples of bridge projects. The report is far from complete given the countless different techniques and processes on the market. A selection of the most common techniques is addressed along with some others that were considered particularly interesting in the scope of the project.

The success of a bridge project depends on good planning and requires a variety of tools, such as new techniques and innovative methods, to solve the obstacles that can arise.

Table of contents

Preface

This project was founded by the Development Found of the Swedish Construction Industry (SBUF) and NCC. Results from the project will act as an input to the European project PANTURA [21].
Another on-going EU-project, named Mainline, has one focus on replacement of bridges was discovered at the start of this project, along with the Accelerated Bridge Construction program in the USA.
Taking into consideration the money spent on these projects, the importance to find innovative techniques and refined methods to improve bridge construction is evident. The results from these projects are especially needed in urban areas or at location where the time window for replacing a bridge is brief.
This SBUF-report “Snabba brobyten och brobyggnationer” has been executed by Alexandre Mathern & Tobias Larsson, NCC Teknik, in Göteborg, Sweden.
In our work with finalizing this report we have had the help of a reference group with the following people and their companies:

• Magnus Alfredsson	NCC Construction AB
• Anders Carolin	Trafikverket
• Magnus Knutsson	SEKO
• Johan Lundblad	NCC Construction AB
• Jan Olofsson	SKANSKA

We would like to express our gratitude to the persons in the reference group for their enthusiasm and ideas. Finally thanks go to the companies of the reference group that have sponsored with time their own work for the reference meetings.

Göteborg, Sweden 2013

Tobias Larsson, project leader.

1. Introduction

1.1. Background

A considerable proportion of today's bridges in Sweden and Europe, especially on the railway side, is obsolete and need to be either repaired or replaced [24] [26]. With a history of increasing allowable loads and traffic on road and rail networks, the need for maintenance and construction works increases at the same time as the sensitivity of the transportation networks to traffic disturbances.

In urban areas for instance, the available space for construction works is often very limited and traffic rerouting or disruptions are not easily granted. Furthermore, several studies pointed out the important costs for society generated by traffic congestion [27] [29].

For construction works on railway lines, the time is usually limited to the interval between two trains and hefty fines can be charged to the contractor in case of unplanned delays or disruptions in traffic. In Sweden, the accepted traffic interruption on railway lines is usually between 12 and 72 hours, while the most important lines should in principle not be closed at all [12].

This means that it is necessary to develop solutions for bridge construction that minimize traffic disturbances to increase efficiency and profitability. Different techniques of prefabrication and industrialized construction become therefore relevant to meet the stringent requirements for short construction times.

The main argument calling for the use of accelerated bridge construction is therefore the minimization of traffic disturbances.

1.2. Definitions

Accelerated bridge construction can be defined as *"bridge construction that uses innovative planning, design, materials and construction methods in a safe and cost-effective manner to reduce the on-site construction time that occurs when building new bridges or replacing existing bridges"* [2].

Accelerated bridge construction is defined in comparison to **traditional bridge construction**, which refers to bridge construction with no effort to reduce the construction activities on-site. It usually includes time-consuming activities performed on-site in a stepwise manner, such as excavations, installation of scaffolding and falsework, reinforced concrete activities, painting of steel members, etc.

Bridge replacement consists in building a new bridge at the same location as the old bridge or in replacing some parts of the old bridge (often the superstructure). If the new bridge is built next to the old in order to be able to replace it, it can also be considered as a bridge replacement [12].

On-site activities and **on-site construction time** refer to maintenance, repair, demolition or construction works carried out at the location of the bridge. It often corresponds to an area that is not ideal for conducting construction works, for instance with traffic, over a river, at heights, over steep slopes or in a protected area, etc.

In the case of the replacement of an existing bridge or part of it, the construction operation will certainly affect for some time the traffic that passes the bridge. The replacement of an existing bridge or the construction of a new one also risks to affect the traffic under the bridge.

A way to reduce the construction works conducted on-site is to use **prefabrication**. Elements of the bridge can be prefabricated in a factory or at a **temporary construction site** established close to the final assembly location in order to simplify transport of large elements. This temporary site can even be in the immediate vicinity of the final location of the bridge if it allows reducing the constraints.

1.3. Aim and limitations

The aim of this project was to perform a scan for innovative solutions used in different countries to accelerate the replacement and construction of bridges.

As a result of the project, this report describes a non-exhaustive number of technical solutions and on-site assembly methods for accelerated replacement or new-construction of bridges. The main focus of the project is the minimization and efficiency of on-site construction activities and of the diminution of their impact on traffic.

The scan did not only focus on new techniques, but also on proven ones that are ready for implementation. Therefore some of the techniques identified have already been used for years in some countries, while others have been developed more recently and only applied in few projects. The scope of the study covered prefabrication solutions, methods of transportation and installation of large prefabricated elements, production aspects for construction sites with reduced working space, etc.

This project did not consider the decision to replace an existing bridge or build a new bridge. Therefore the choice between bridge replacement or alternative methods for bridge reparation or strengthening is not discussed.

1.4. Selection of accelerated construction techniques

As previously mentioned, the main criteria considered in the study for the identification and selection of techniques is the **time of construction on-site**. Other related criteria were also considered to achieve accelerated bridge construction and to minimize associated disturbances. Therefore the following criteria were also taken into account:

- **Level of prefabrication**

The factor with the greatest impact on the duration of on-site works is probably the level of prefabrication. By the prefabrication of elements of the bridge at an off-site location, either in a remote factory or at a nearby temporary construction area, the works on-site can be reduced to the installation of these prefabricated elements.

- **Cost**

Nowadays, the bids for bridge construction projects are most often assessed solely on the lowest price; therefore the cost of a technique is the main parameter determining its use.

However, it should be mentioned that the cost of a new technique is usually higher with its first implementation and can often be reduced considerably with further applications. Reasons for that are numerous, for instance the additional tests and design works required at the beginning, the consideration of risks and other unknowns, or the reduced number of suppliers and competition, etc.

The reduction of the construction time on-site and the use of prefabricated elements also present opportunities to reduce construction costs. In many cases, prefabrication permits to reduce or avoid using costly temporary structures (e.g. formworks, temporary supports or temporary bridge). Resources, such as lifting equipment, are required during less time; therefore reducing their rental costs or making them available for something else. Prefabricating elements off-site in a controlled environment minimizes the risk for delays due to adverse weather conditions, which often have important economic impact.

Besides, it should be mentioned that accelerated bridge construction can reduce secondary direct costs for the bridge owner, such as traffic management costs or indirect costs such as user delay costs. If a better durability is achieved, life-cycle costs can also be reduced. These parameters among others should be taken into account in order to determine which alternative is the economically most advantageous, as they could counterbalance the higher initial costs of a solution.

Germany, for instance, recognizes the importance of accelerated construction on critical highways with heavy traffic. When submitting tenders, contractors are invited to propose solutions for shorter construction times than those specified by the client. This "acceleration" is then taken into account for the award of the contract [7].

- **Constructability**

Besides speeding up the process, a good constructability lowers the risk for construction defects and mistakes which may cause long additional delays. It also contributes to improving the work-zone safety and the working conditions for the workers.

- **Weight**

The weight of the prefabricated elements is also an important parameter to take into account for accelerated construction. Lighter elements reduce the need for heavy lifting equipment or make it possible to use alternative installation methods, which often simplify and speed-up the installation. A reduced weight can also allow pre-assembling more elements prior to the installation. For instance complete superstructure elements can be installed with the slab already on the frame and possibly even with integrated edge beams and barriers.

Besides, a lower self-weight of the superstructure can be interesting to reduce the foundation costs, reach longer spans (e.g. bridges over highway without intermediate support), or for bridges in seismic areas.

- **Durability**

A good durability reduces the need for maintenance and repair works that often represent important costs and cause nuisances during the life-time of the bridge. It also improves the travel experience for the road users.

Other criteria that were not taken directly into account for the selection of techniques are among others the impact on the environment and the impact on safety, health and welfare of road users and locals. However, it is considered that accelerated construction has in general a positive impact on these aspects by reducing the duration of construction works and traffic congestion at sensitive locations.

1.5. Overview

Solutions of prefabricated bridge elements identified in the study are presented in **Chapter 2**. Conventional and more recent materials for prefabricated bridge elements are also briefly described.
Different methods for the transportation and installation of prefabricated bridge elements, pre-assembled superstructures or complete bridges are described in **Chapter 3.**
In **Chapter 4**, methods and processes that were used to achieve accelerated construction of bridges in singular projects are presented.

2. Prefabricated bridge elements

During this study, it was observed that different methods and solutions, almost always using prefabricated elements, were used to reduce the construction time, minimize traffic disturbance or increase the profitability. It could also be noticed that the use of prefabricated bridge elements differs extensively between countries, especially the use of concrete bridge elements.

A selection of identified prefabricated techniques will be presented in this Section.

2.1. Materials

2.1.1. Concrete

Concrete is today the most used construction material for bridges, usually as reinforced concrete or prestressed concrete. Concrete is traditionally cast on-site and despite the emergence in the last years of prefabricated concrete elements, the construction of a bridge is almost always associated to time-consuming on-site activities related to concrete works. For instance it usually requires a repetition of the following activities performed one at a time:

- installation of formworks and temporary supports,
- placement of steel reinforcement,
- concrete casting, consolidation and finishing,
- concrete curing,
- removal of formworks and temporary supports,
- repair of defects.

Besides, the type of works required by on-site casting of concrete can affect negatively the working environment. It can also lead to risks for delays, for instance if the fresh concrete does not fulfil the requirements when it arrives on-site or if it is required to remove some newly-cast parts due to unacceptable defects. As the prefabricated elements are cast in a controlled environment it is often possible to obtain a more even quality than on-site, and thus a better durability.

2.1.2. Steel

Steel is another common material for bridges, used to prefabricate structural elements such as piles, piers and beams, etc.; or other miscellaneous elements such as barriers. The prefabrication of the elements and their lower weight compared to resistance-equivalent concrete elements make it a suitable material for rapid bridge construction.

2.1.3. Fibre-reinforced polymers (FRP)

Fibre-reinforced polymers (FRP) are relatively new materials in the construction industry, although they have been extensively used for many years in other industries, e.g. aeronautics, shipbuilding, automotive, wind-power, etc.

FRP are composite materials composites made of fibers, usually in carbon, glass or aramid, combined with polymer resins to form different structural shapes. FRP elements can be manufactured by different processes such as pultrusion, vacuum infusion, hand lay-up, etc.

One of the main advantages of FRP is that they offer a high strength to weight ratio. FRP have also a good resistance to fatigue and corrosion [2].

Until now, the use of fibre reinforced polymers (FRP) in bridge construction has mostly been limited to footbridges, to strengthening of existing bridges and to deck panels for road or railway bridges. There has not yet been a lot of applications with use of FRP for beam elements except for footbridges.

FRP reinforcing bars have also been used, but their application remains limited due to the difficulty of obtaining bent FRP reinforcing bars.

2.1.4. Timber

Timber has been used for bridge construction since time immemorial, but it was rather left out in favour of concrete and steel in the second half of the 20th century. Interest is now growing again for use of timber in bridge construction, especially because of environmental reasons and the development of glued laminated timber products and new structural solutions such as stress-laminated timber decks.

2.1.5. Ultra-high performance fibre-reinforced concrete (UHPFRC)

Ultra-high performance fibre-reinforced concrete (UHPFRC) is a relatively new cementitious material, developed in the 1990s. Its name comes from its improved strength, ductility under tension and durability properties [25]. It is characterized by a characteristic compressive strength of more than 150 MPa and up to 250 MPa [28].

It is mainly the better homogeneity of its microstructure compared to ordinary and high-strength concretes that explain the improved strength and durability properties of UHPFRC [25]. The fibres contribute to the ductility of the material and make it possible to get rid of passive reinforcement [28]. It also presents a very low creep and shrinkage [8].

The relatively high price of UHPFRC, the lack of adapted solutions specifically developed for it, and the need to adapt design methods explain to some extent the limited applications of the material to date; used mostly in the USA and France [25].

2.2. Superstructure

2.2.1. Steel girders with concrete top flange – Preco-beams

Constructive solutions based on the embedment of steel I-beams or T-beams in concrete girders or concrete decks have already been used for many years.

In the last years, this type of solutions has been developed further in the framework of the European project Preco-Beam [22]. The prefabricated composite beam developed is composed by steel beams embedded in a prefabricated top flange in reinforced concrete that also serves as pre-slab for the cast-in-place concrete deck, as illustrated in Figure 2.1.

Figure 2.1. The Preco-Beam concept (Source: ArcelorMittal)

The steel-beams used for the Preco-beams are obtained by oxy-cutting the flange of an I-beam, in order to obtain two T-beams with a special cutting geometry, as shown in Figure 2.2.

Figure 2.2. Oxy-cutting of a steel I-beam to obtain two special T-beams used for Preco-beams [8]

The special geometry of the cut in the flange presents several advantages. It is obtained by a unique continuous cut, which is fast and minimizes the loss of material. The shape of the flange ensures shear transmission between the concrete and the steel, therefore making unnecessary other more expensive processes such as welding for shear studs or drilling holes for rebars. Good resistance to fatigue is also achieved thanks to the curved lines of the cut [8].

Besides, the concrete top flange contributes to improving the safety with regard to buckling and to minimizing the need for anti-corrosion treatment of the steel elements.

Preco-beams are economically interesting for bridges with short to medium spans up to 40 m [8]. The prefabrication of the beams and the use of the top-flange as pre-slab for the deck lead to short on-site construction time.

2.2.2. I-beams in UHPFRC

I-beams in UHPFRC were used for the enlargement of the Pinel Bridge, near Rouen, France. The new bridge crosses railway tracks and has a span of 27 m and a width of 14 m. The concrete deck was cast on 17 prestressed I-beams. The beams of type ITE® have a bottom flange of 800 mm by 150 mm, and a web of 470 mm in height and 70 mm to 150 mm in thickness.

Figure 2.3. Installation of I-beams in UHPFRC at the Pinel Bridge (Source: Setra)

2.2.3. FRP girders

FRP girders have been used for several footbridges but until now very seldom for road or railway bridges.

In particular, three road bridges were built with FRP girders in Spain and are among the first vehicular bridges of this kind in Europe. The first one is a 46 m long bridge with four continuous spans, built in 2004 along the highway leading to the Asturias Airport [19]. The bridge is made of three FRP girders with trapezoidal cross-section, manufactured by hand-lay up of carbon fibre pre-pegs around a stay-in-place polyurethane mould. The girders were transported in two pieces and joined on-site using adhesive. The resulting 46 m long girders weighted each less than 5 tonnes and they could therefore be installed with only one crane in three hours.

The two other bridges were built in 2007 along the M-111 highway, close to Madrid, see Figure 2.4. They are identical with a length of 34 m and three simply-supported spans, the longest of 14 m [19]. The experience of the previous bridge called for several changes in order to reduce the costs of the FRP girders. Among others, a combination of carbon fibres and cheaper glass fibres was used and the girders were designed with a U-cross-section in order to avoid the need for stay-in-place moulds.

For the three bridges, the concrete deck was cast on stay-in-place glass fibre formworks placed on top of the FRP girders in order to speed-up the construction.

Figure 2.4. Installation of FRP girder at one of the M-111 bridges (left) and view of the completed bridge (right) (Source: Acciona)

2.2.4. Bridge-in-a-Backpack – Concrete filled FRP tubes

Another technology using FRP for the main structural elements of bridges is called Bridge-in-a-Backpack. The technology is based on tubular FRP arches, which are filled on-site with self-compacting concrete. It has been developped at the University of Maine since 2001.

The FRP tubes fulfil three main functions: they act as formwork for the cast-in-place concrete cores, they confine the concrete and reinforce the arches, and finally they protect the concrete from the environment. The building sequence and the different elements of the Bridge-in-a-Backpack technology are described in Figure 2.5.

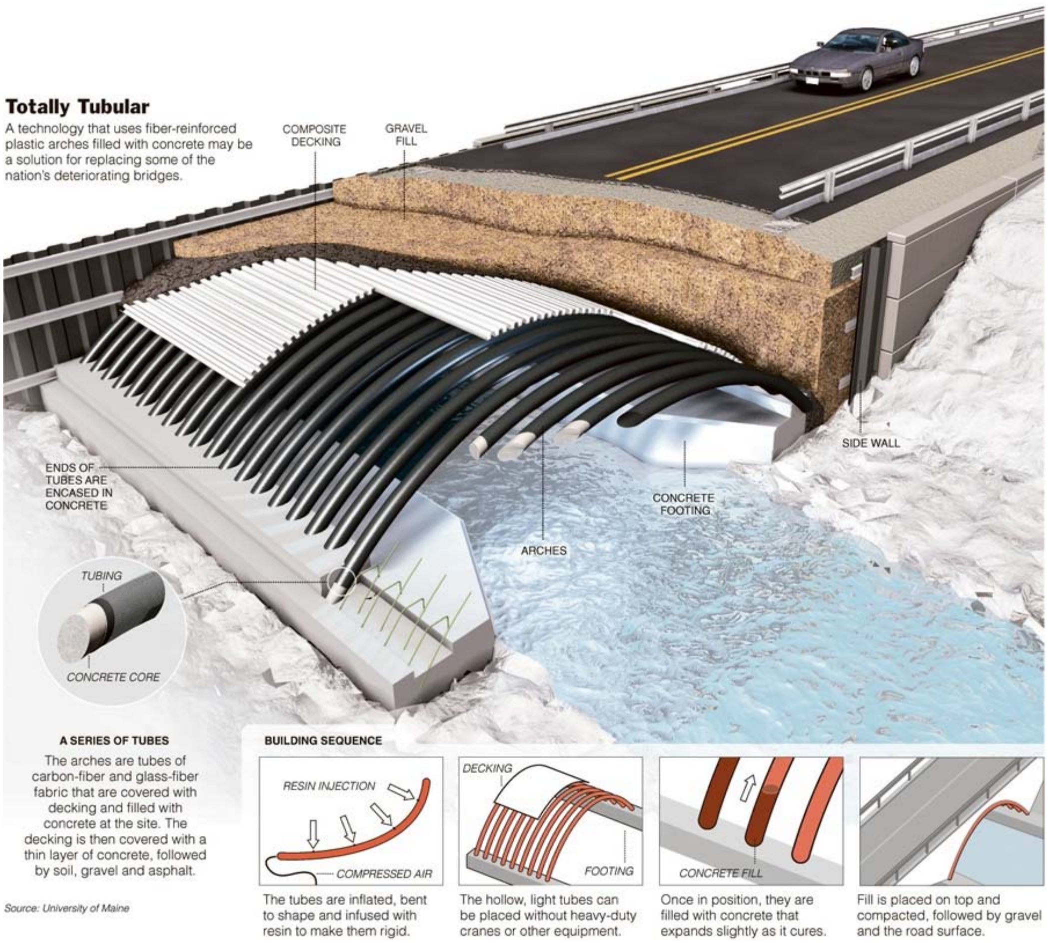

Figure 2.5. Description of Bridge-in-a-Backpack technology (Source: University of Maine and New York Times)

This system is mostly adapted to short span bridges crossing streams (see Figure 2.6), but has also been used for overpass. In 2012, there were more than 10 bridges built with this system in the USA, whose spans range from 8 m to 16.5 m [23].

The arches can be produced in factory in a few hours. They can then be transported to the construction site in relatively small trucks and carried by two or three workers on-site. Bridge replacements carried out using this system were reported to have taken less than two weeks including the removal of the old bridge [23].

Figure 2.6. Bridge-in-a-Backpack built over the Royal River in Maine, USA (Source: Innovative Products)

The American Association of State Highways and Transportation Officials (AASHTO) developed specifications for the design of concrete filled FRP tubes for flexural and axial members [6].

2.2.5. Hybrid-Composite Beam

The Hybrid-Composite Beam is an advanced type of beam made of different materials, which has been developed by John Hillman, since the mid-1990s. As shown in Figure 2.7, it consists of a concrete arch tied by external galvanized prestressing strands and encased in a fibre-reinforced composite box. The aim of the design is to optimise the use of the concrete working in compression and of the tensile strands. The remaining space in the box is filled with low-density foam. The main advantages of this technology are therefore its lightness and its resistance to corrosion. It has been reported that it weights around 10% of the weight of a concrete beam with the same capacity [23].

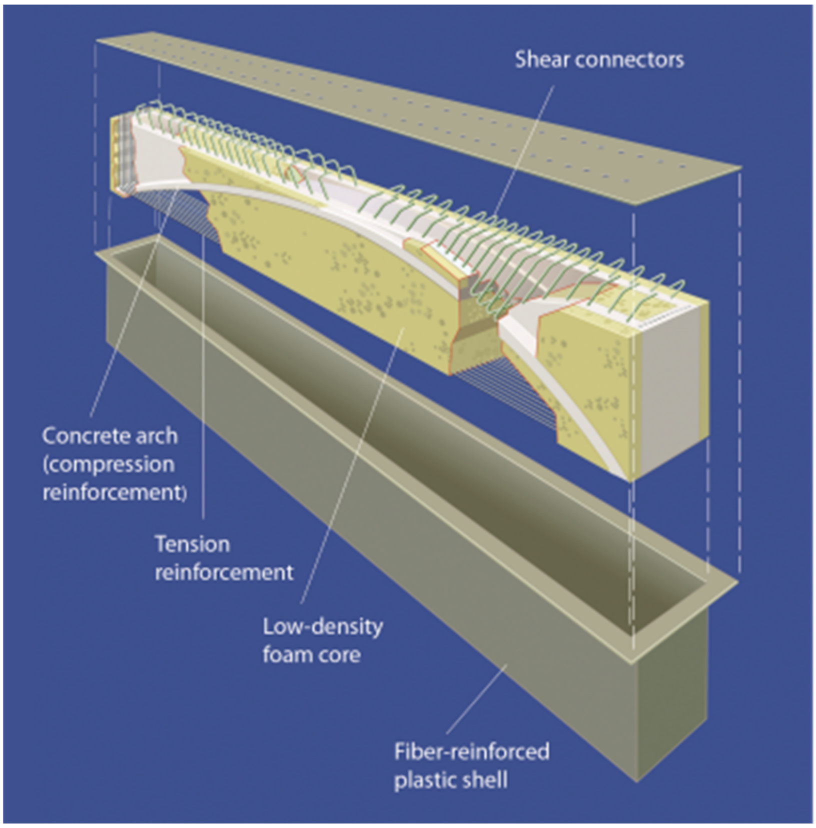

Figure 2.7. Hybrid-Composite Beam technology (Source: Reinforced Plastics)

Since 2007, around 10 road and railway bridges have been built in the USA using the Hybrid-Composite Beam technology.

2.2.6. Stress-laminated timber decks

Stress-laminated timber decks are made of timber elements, either in sawn lumber or in glued laminated timber (glulam), transversally post-tensioned together [2]. The friction between the laminations under transversal compression ensures the distribution of concentrated loads onto several laminations. This type of deck can be used for bridges with short or medium spans up to 35 m.

Stress-laminated timber decks made of glulam laminations were used to build a temporary bridge in Solna, Sweden. The bridge has a total length of 180 m and a width of 30 m and it is continuous over 12 spans, of which the longest is approximately 17 m (see Figure 2.8). It actually consists of four structurally independent superstructures, the two central ones carrying two traffic lanes each and the two on the sides for pedestrian and bicycle [14]. The bridge was designed for 10 years, but is planned to be in-use for only three years.

Figure 2.8. Temporary bridge with stress-laminated timber deck in Solna, Sweden (Source: Lennart Johansson, Stadsbyggnadskontoret, Stockholms stad)

The bridge crosses an important motorway and a railway line; hence the main requirement of the project was that the traffic on these networks should not be interrupted.

As shown in Figure 2.9, the glulam elements were pre-assembled with butt joints in order to satisfy continuity. Another difficulty of the project was to prestress the decks as the available space between two adjacent bridges was very limited [14].

Figure 2.9. (Source: Eric Stering, DN)

Stress-laminated timber decks can also be interesting when it comes to replacing the superstructure of old concrete bridges, as the reduction in dead-weight allows to carry heavier loads without changing the substructure.

2.2.7. Partial depth concrete deck panels

Prefabricated partial-depth concrete deck panels are often used for bridges with steel or concrete girders. The need for temporary formwork for the deck is avoided, whose installation usually constitutes one of the most time-demanding activities on-site.

One of the first large scale applications of this type of semi-prefabricated deck panels was the construction of a new highway bridge over the Wupper River Valley, near Wuppertal, Germany, completed in 2006. Full-width partial-depth concrete deck panels of 18 m wide were used for this 420 meter long composite bridge with steel U-shaped box girder with inclined struts [13].

Some of the partial-depth panels were already placed on top of steel girder before longitudinal launching, which made it possible afterwards to install the rest of the panels without disturbing nearby traffic. The reason why not all panels were placed on the bridge before launching was that it would have become too heavy with regard to the capacity of the launching equipment.

Figure 2.10 shows some steps of the construction of the Wupper River Valley Bridge. Figure a) represents the U-box shape steel girder with the shear studs on the top flange. On Figure b) the diagonal struts that support the deck beyond the girder are illustrated. On Figures c) and d), the semi- precast slabs are installed on the top flange of the steel girders and the shear studs from the steel girder were fitted into the openings in the panels. These openings were filled with high strength concrete before casting the final concrete to complete the bridge deck. The panels were placed on soft polymer strips to seal the joints between the panels and the top flange of the steel girder. As can be seen on Figure c), transversal rebars are mounted on the panels before installation [7].

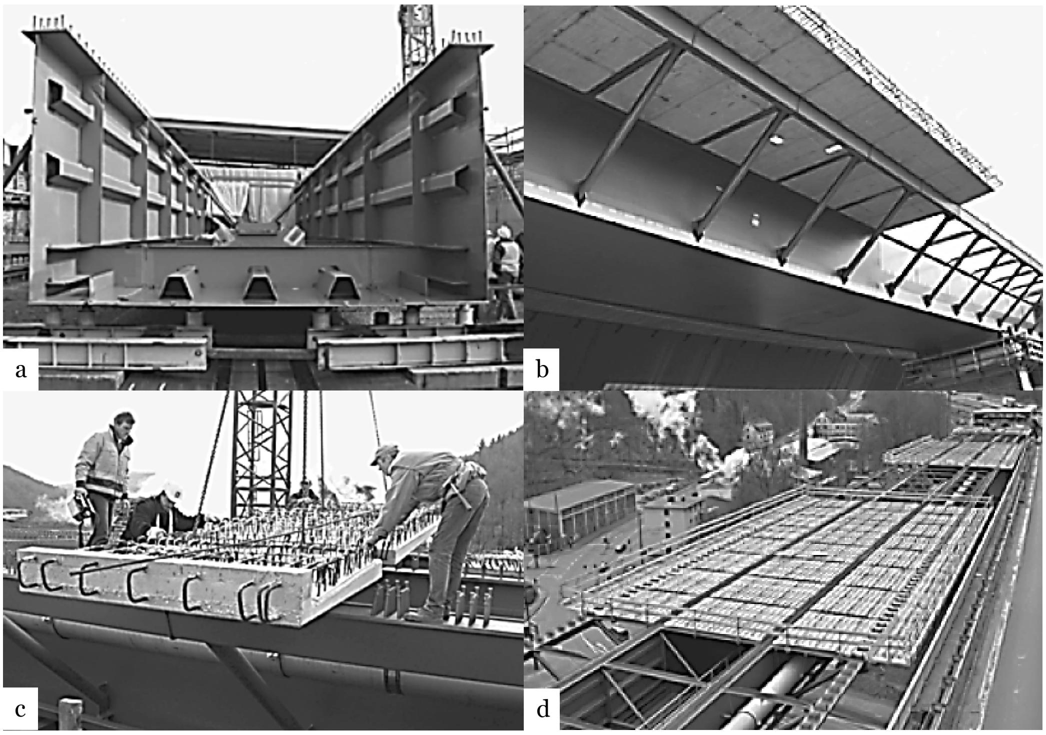

Figure 2.10. Installation of the Wupper River Valley bridge (Source: Strassen NRW, from [7])

2.2.8. Full-depth concrete deck panels

A further step towards accelerated on-site construction consists in prefabricating the entire deck in the form of full-depth concrete panels. The panels are prefabricated in a controlled environment, usually in a factory, and transported to the site for the final assembly on the girders (see Figure 2.11). In this way, concrete casting activities on-site are reduced to a minimum as concrete is only poured at the joints between the elements. The prefabricated elements may even integrate edge beams and barriers.

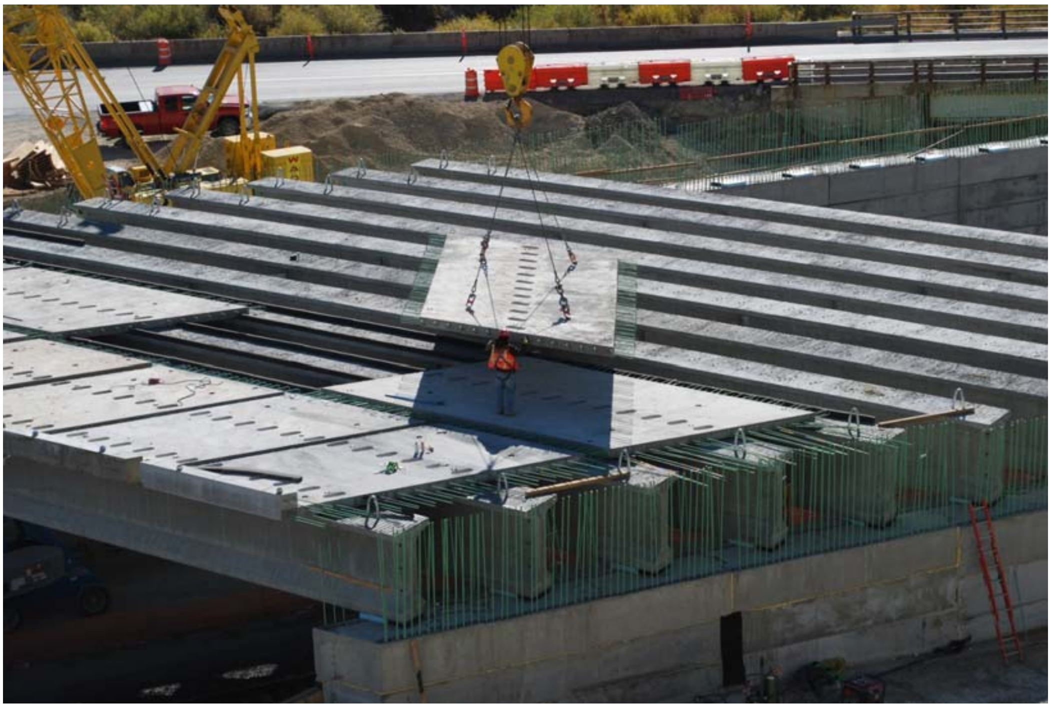

Figure 2.11. (Source: Utah Department of Transportation)

There exist different systems to connect the slabs to each other. One possibility is to place reinforcement and pour concrete in a gap between the panels. Another possibility is to use dry joints, i.e. the prefabricated concrete panels are provided with "overlapping concrete tongues" that fit into each other. Concrete is then poured into a void in the concrete panels over the top flange of the girder, in order to obtain composite action [10].

The main advantage with the last mentioned method is that it reduces the amount of man-hours at the construction site as well as the construction time.

2.2.9. Full-depth waffle deck panels in UHPFRC

This type of prefabricated deck panels in UHPFRC consists in a thin slab, reinforced in transversal and longitudinal directions by ribs, giving the panels a waffle shape, as shown in Figure 2.12. The panels are prestressed by pre-tensioned strands implemented in the transversal ribs.

Once the prefabricated elements are placed on the steel frame, the elements are connected by cast-in-place concrete joints and compressed by longitudinal external prestressing running between the longitudinal ribs. The slab is then connected to the steel frame by injection of high-performance mortar in the voids of the slab above the upper flange of the steel beams. [8]

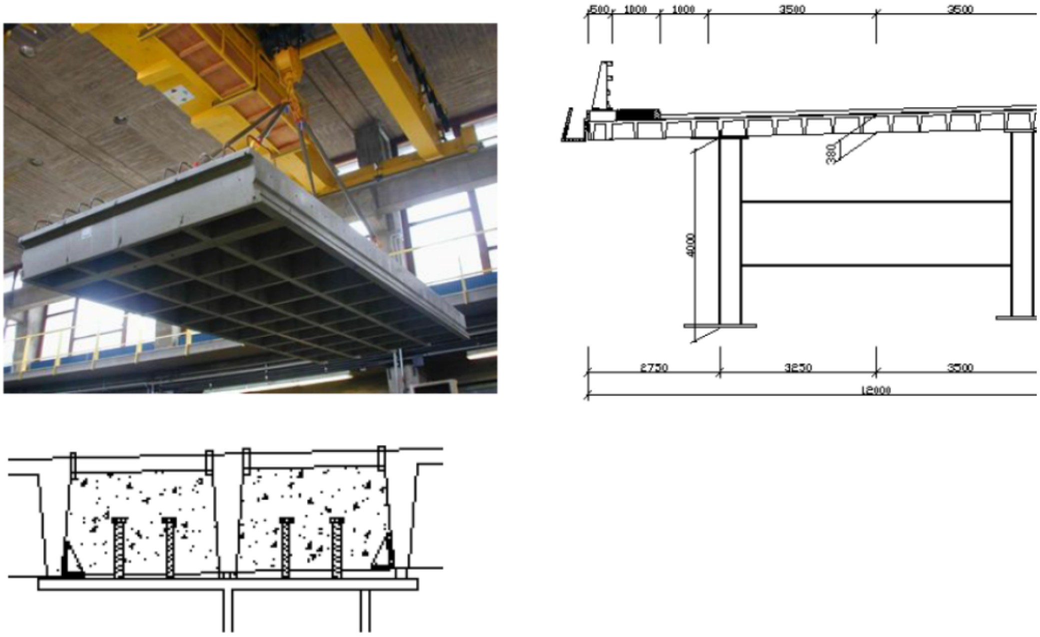

Figure 2.12. Full-depth waffle deck panel in UHPFRC and sketches of connection to steel girders [8]

The main benefits from this solution compared to a traditional cast-in-place deck with the same capacity are the weight reduction and the improvement in terms of durability due to the high-strength and low permeability of the UHPFRC. The weight of the deck is almost reduced by half and the one of the steel beams can therefore also be reduced by 15-20 % [8].

The low shrinkage and creep of UHPFC make the use of longitudinally prestressed slab elements particularly beneficial. It ensures that the compression stays in the slab without affecting the steel frame [8].

The European project Nr2c [20] showed that waffle deck panels can also be very interesting economically for bridges with very short spans of less than 10 m, without the use of an additional steel frame [8].

This solution has been developed and thoroughly tested in the framework of the French project MIKTI on steel-concrete composite structures. It is planned to use it in a real project that has not been built yet: the deviation of Livron Loriol on RN7, France [8]. The waffle deck panels developed for this project consist of a 5 cm thick deck slab and ribs spaced 60 cm apart. The panels have a total height of 38 cm and are equivalent in weight to a slab of less than 15 cm [8].

Waffle Bridge Deck Panels are also developed in the USA at Iowa State University, where a demonstration bridge of 18 m long and 10 m wide consisting of 14 waffle panels has been built and is being monitored.

2.2.10. FRP deck panels

The two main types of FRP deck panels are pultruded hollow sections and hand layup sandwich panels, see Figure 2.13. Pultruded panels are formed by adhesive bonding of hollow sections. Their fibres are mostly oriented longitudinally due to the automatic process of manufacturing. Sandwich panels on the other hand can carry the load in two directions and are therefore more adapted to carry concentrated loads [2].

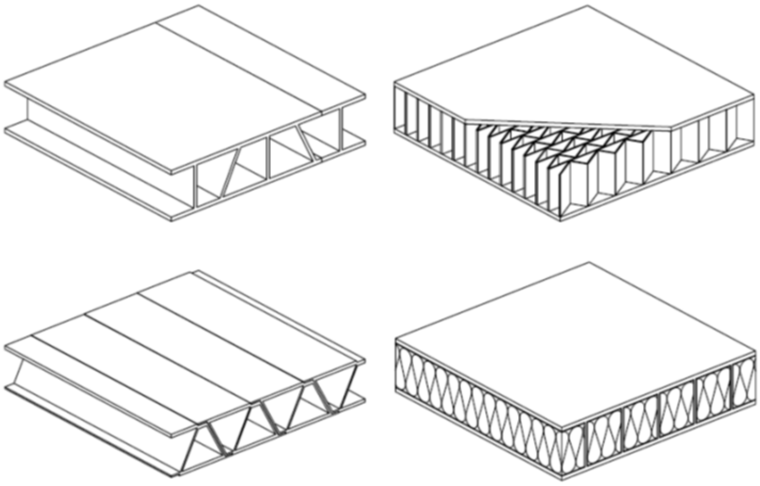

Figure 2.13. Different systems for FRP bridge deck panels; pultruded hollow sections (left) and manually laid-up sandwich panels (right) [17]

The resistance to corrosion of FRP makes it an attractive material to use for bridge decks. Indeed bridge decks are traditionally in concrete and prone to deteriorate due to their exposure to moisture and de-icing slats. FRP deck panels can also be assembled off-site on steel girders for small- to medium-span bridges, in order to obtain a relatively low-weight prefabricated superstructure.


Figure 2.14. Friedberg bridge (Source: ASV Gelnhausen)

FRP deck panels can also be used for upgrading old bridges, the lighter weight of the deck offering an increased load capacity for the bridge.

New connections between FRP deck panels and steel girders for fast erection are being developed in the EU-project PANTURA [21].

2.3. Connection between prefabricated elements

2.3.1. Grouted sleeve reinforcing bar couplers

The transmission of forces between the reinforcement of two prefabricated elements can be ensured by injecting grout in a steel connector embedded in one of the prefabricated element, as shown in Figure 2.15 [9].

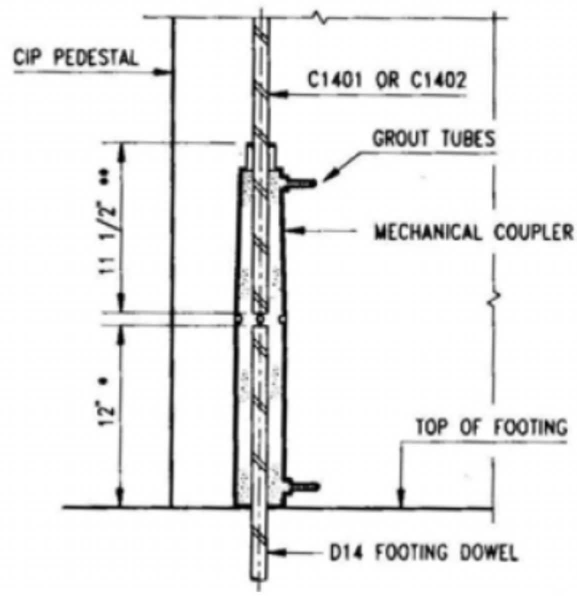

Figure 2.15. Grouted sleeve reinforcing bar coupler [9]

This type of couplers has been used in the building industry but is rather new to the bridge industry. They have been used in some bridge projects in different states of USA, for instance in Florida for the Edison bridge, built in 1992, to connect columns to footings and caps to columns [9].

The use of this connection system can accelerate and simplify the erection of prefabricated elements. It has been shown that this connection can develop more than 150 % of the yield strength of the bars and avoid the need for lapping of the bars [8]. As moments are transmitted between the prefabricated elements, the structure can be designed as cast-in-place.

Figure 2.16. Installation of pier cap with grouted sleeve reinforcing bar couplers for the Bridge over Keg creek, Iowa, USA [Source: AASHTO]

3. Installation of prefabricated elements

Nowadays, many different methods are used to erect bridges, depending on the location of the bridge and its structural system. During this study, many different methods were identified for the installation of prefabricated elements either transported to the construction site or built next to the final location of the bridge. Not all the possible methods of installation will be commented here as there exist countless variants of them and combinations of them are often used. The selection of methods described in this report is based on the frequency of use in the studied projects and the intention to cover different types of methods.

Most of the prefabricated elements described in Section 2 can be installed by conventional cranes, see Section 3.1. In the following paragraphs, other methods are described, which can lead to easier and faster installation of prefabricated elements, for instance when cranes cannot be installed on the feature to be crossed (e.g.: road with heavy traffic, river channels, deep valleys, terrain with bad ground conditions), or if the structure is repetitive. Some of these methods can also be used for the installation of entire superstructures or entire bridges.

3.1. Conventional and heavy lifting cranes

Cranes constitute the most common lifting method on construction sites and can be used to install most types of prefabricated elements.

In order to carry heavy elements or to ease the installation of long elements such as girders, more than one crane may be needed. Figure 2.14 shows the installation with two mobile cranes of a complete superstructure with steel girders and FRP deck.

Today, mobile cranes have a capacity of more than 100 tonnes at a radius of 20 m. Availability of and costs for using large mobile cranes varies considerably and are therefore in many cases not an option.

3.2. Longitudinal launching

Longitudinal launching is a common method to install bridges over hardly-accessible areas, such as valleys with steep slopes, rivers, or environmentally protected areas, see Figure 3.1. It can also be chosen in order not to affect the traffic under the bridge (roads, railways or navigation channels).

The method consists in building the superstructure of the bridge at a concentrated work area at one or both of the abutments.

When launching a bridge, a launching nose is used. The launching nose is mounted to the main girders in order to reduce the utilization of the structure during the launching. The design of the nose is made to be as light as possible and it can be inclined to facilitate traveling of the bridge girders on the intermediate supports.

Often some type of arrangement with hydraulic jacks is used to push/launch the bridge to its final position. Temporary supports are placed on the piers to facilitate the launch with low friction materials or rolls and often the temporary supports have larger areas than the final bearings to reduce the contact pressure on the structure, see Figure 3.2. The bridge structure is also guided by vertical supports to prevent the bridge from sliding off the supports.

It offers the advantage of minimizing the disturbance to surroundings, and possibility to increase worker safety with the erection technique.

The method is often used in Europe to install both steel and concrete bridges. Different names can be used for horizontal launching depending on whether the bridge arrives to the site in one piece or if it is first assembled at the work site or cast as increments, however the launching method is basically the same.

Figure 3.1. Horizontal launching of the Iowa River bridge, 92 meters long [4]

Figure 3.2. Temporary supports used during the launch to minimize the friction at the piers [4]

3.3. Lateral Launching

Lateral launching consists in building a new bridge parallel to its permanent location and then moving it laterally into place. It is particularly adapted to the construction or replacement of existing bridges under railways. The method is used both for rigid framed bridges and bridges with approach spans.

3.3.1. Lateral skidding/sliding

There exist various methods for lateral launching by skidding or sliding that can be used to install bridge superstructures or whole bridges.

One of the largest lateral launching operation to date was the installation of two bridges of 3500 tonnes and 12500 tonnes in Boissy-Saint-Léger, France under the lines of the Regional Express Network A (RER A), see Figure 3.3. The largest bridge was 60 m in length and 10 m in height.

The two bridges, separated by only few meters, were built around 40 m next to their final position and installed by the Autoripage® and Autofonçage® methods, two variants of lateral launching developed by JMB Methods. The installation of the two bridges was performed in 28 hours [3].

The used methods allowed to spread the load of the bridges over a large surface and to limit the pressure on the soil to 50-70 kPa [3].

Figure 3.3. Installation of two bridges in Boissy-Saint-Léger, France by the techniques of Autofonçage® (left) and Autoripage® (right) (Source: Freyssinet)

3.3.2. Flotation

In case the location of the bridge permits it, the lateral installation of the bridge by flotation can become an economical alternative to skidding or sliding. The two main things required are an impermeable soil and a nearby source of water.

These conditions were met for the installation of a bridge under railways at Saint-Pierre-du-Vauvray, France, where flotation was preferred to lateral skidding (Figure 3.4). A sheet pile enclosure was excavated and filled with water in order to move the 900 tonnes rigid-frame bridge. The proximity to the Seine River, where 2000 m^3 of water were pumped, made this alternative the most economical. The translation of the bridge was performed in one hour and the traffic stop was limited to 22 hours in total, including removal of the old tracks, excavation works, water filling and installation of the new tracks [5].

Figure 3.4. Installation of a bridge by flotation [5]

3.4. Rotation

The installation of a bridge by rotation around a vertical axis passing by one of the piers can be an attractive alternative when an adequate area for the prefabrication is available alongside the obstacle to be crossed. The bridge can then be constructed in a safe area on the ground without disturbing the traffic, which simplifies the construction works, for instance by allowing the use of scaffolding.

This technique can be used to install large bridges with spans of more than 100 m. The equilibrium of the cantilever structure must be satisfied during the rotation, as for the cantilever method. It is therefore well-adapted to cable stayed bridges with prestressed concrete slabs. For bridges with three spans, a double rotation can be performed to join the two halves of the bridge, prefabricated on each side of the obstacle to be crossed.

Figure 3.5 shows the rotation of a cable stayed bridge over the Meuse River in Huy, Belgium, in 1987. With a span of 168 m and a weight of 16 000 tonnes, it became the heaviest bridge installed by rotation at that time.

Figure 3.5. Cable stayed bridge installed by rotation in Huy, Belgium (Source: Duchene)

Another interesting application of this method for smaller structures was the installation of eleven bridges over highway RN 10 between Belin-Beliet and Saint-Geours-de-Marenne, France, in 2000. Rotation was preferred to building the bridge at an elevated height over the highway and to the longitudinal launching of a prefabricated bridge, as it appeared to have less impact on traffic and to be more economical [11]. The large central reserve of this 2x2 lanes highway (approximately 13 m in width) allowed to build the bridges on scaffolding on the central reservation of the highway.

The eleven two-spans bridges were almost identical, with a prestressed concrete slab of 50 m in length and 7.5 m to 9 m in width, for a weight varying from 820 tonnes to 1000 tonnes, see Figure 3.6.

One of the particularities of this operation was that the extremities of the prestressed concrete deck were supported during the rotation by ties anchored on a temporary tower placed on the deck over the central support.

The rotation of each bridge was completed in less than one hour, and one bridge was installed approximately every three weeks.

Figure 3.6. Installation by rotation of one the 11 bridges over RN10, France [5]

3.5. Self-Propelled Modular Transporters (SPMTs)

Self-propelled modular transporters (SPMTs) are high capacity multi-axle transport trailers, which can be used to transport and install prefabricated bridges from an off-site construction location to their final location, see Figure 3.7.

SPMTs are computer controlled and highly manoeuvrable as they are capable of moving or rotating in any direction in the horizontal plane with wheel sets that can rotate 360 degrees. SPMTs can also be combined longitudinally or transversally while being programmed to function as a single unit [2]. An SPMT unit usually has four or six axle lines with four to eight tires per line. SPMTs are propelled by an on-board hydraulic power pack connected to hydraulic drive motors on several axes. The capacity is around 40 tonnes per axle line.

SPMTs have been extensively used in other industries to transport large and heavy components, for instance in the petrochemical, offshore and power and ship-building industries.

SPMTs can be used to transport and install prefabricated complete bridges or large prefabricated elements built at an off-site construction site distant up to few kilometres from the final location of the bridge. In case of bridge replacement, they can also be used to remove the old bridge and to conduct the demolition works away from traffic.

The use of SPMTs requires an available location to build the bridge near the bridge to be replaced and a feasible route from the off-site construction location to the final destination. A steel frame is usually used to support the bridge over the SPMTs.

More than 30 bridges have been installed using SPMTs in the USA in the last years, and considerably more in Europe where this method used to be more common. The time of installation of prefabricated bridges using SPMTs in USA has been reported to range between 2 and 8 hours [2].

Figure 3.7. Installation of Sam White Bridge using SPMTs in Salt Lake City, Utah, USA (Source: Sarens)

3.6. Launching gantries

There exist countless different methods to erect prefabricated superstructure elements using various types of frames or lifting solutions. A selection of methods that ensure rapid erection of bridges in areas with low accessibility or reduced impact to traffic under the bridge are described in Section 3.6.1 to 3.6.3.

One of these methods consists in the erection of prefabricated bridge elements with a launching gantry, which is an overhead frame equipped with a lifting system and with a length of at least two times the span length of the bridge.

Launching gantries are often used when it comes to building long bridges with medium spans with repetitive span length and curvature. They are usually specially designed for the bridge to be built and the elements to be installed, in order to be self-travelling from pier to pier. However, similar methods can also be used for simple applications such as the replacement of a short-span railway bridge, as described in this section later.

3.6.1. Span-by-span and full-span methods

Launching gantries can be used to install or replace prefabricated bridge elements such as deck panels, girders or full-span superstructures.

Launching gantries are also used to erect superstructures made of precast concrete segments, for which it temporary supports each of the segments until the assembly of the complete span, see Figure 3.8.

The frame is referred to as launching girder when it is installed under the bridge, which can present the advantage of offering a clear working platform over the pre-assembled prefabricated elements but reduces the clear height under the bridge.

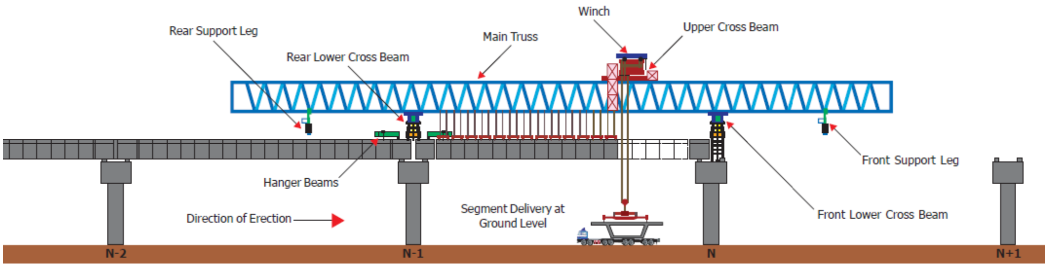

Figure 3.8. Span-by-span erection with launching gantry (Source: VSL)

The launching frame can also be used to install prefabricated full-span girders as shown in Figure 3.9.

These methods are particularly interesting for building bridges parallel to an existing road underneath. It would allow the transport of the element and only require a short traffic stop during the installation of the elements.

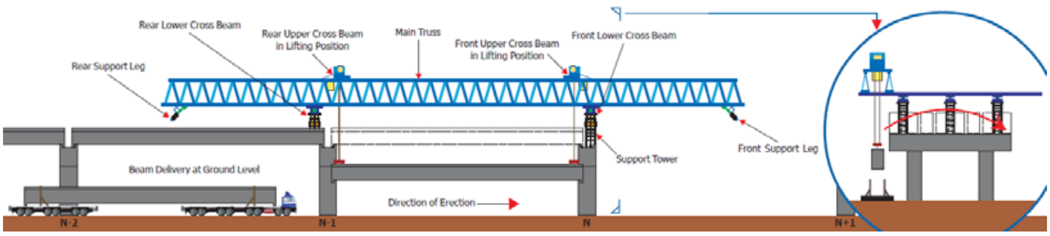

Figure 3.9. Beam erection with launching gantry (Source VSL)

An alternative method to launching gantry or longitudinal launching in order to erect prefabricated full spans for long bridges with medium-span length is the use of bridge carrier with support beam, as illustrated in Figure 3.10. The main advantage of this method is that the prefabricated elements can be transported on the previously completed part of the bridge, which minimises traffic disruptions on existing networks under the bridge. In addition, it can also ease the delivery of the elements over areas that are inaccessible or with poor ground conditions.

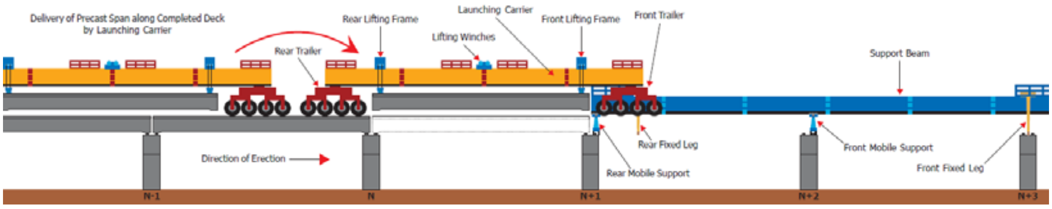

Figure 3.10. Full-span erection with bridge carrier and support beam (Source: VSL)

Railway bridge carriers have been successfully used for many years in Sweden to transport and install prefabricated bridge elements or complete superstructures in remote areas, as the railway tracks often provide the most suitable route to reach the bridge location. The carrier consists in a non-motorized frame-wagon, equipped with hydraulic jacks to lift and lower the elements to be transported.

With this method, very fast replacement of short-span railway bridges can be achieved using prefabricated complete superstructure. It requires normally to stop the train traffic during only 12 to 16 hours to replace an ordinary single span bridge [1].

A development of this method can be used to replace relatively light steel bridges by removing the old bridge and installing the new one with the same bridge carrier in one operation. As shown in Figure 3.11, the technique consists in alternately rotating the two bridges in order to be able to lower the new bridge while lifting up the old one. The two bridges are then rotated again for the installation of the new bridge and removal of the old bridge on the railway bridge carrier. Otherwise, the old bridge is usually dismantle and removed from below the bridge after the train traffic restarted.


Figure 3.11. Bridge replacement by double rotation with railway bridge carrier [1]

3.6.2. Bridge used as overhead crane

Another example of replacement of an existing bridge where the availability was limited was found in France. The bridge, where one of two stretching over a canal, the fact that there were two tracks available at the construction site made it possible to redirect all traffic to one track with speed restrictions [7].

The new bridge was delivered to the site along the track, Figure 3.12. Extension brackets were mounted on both ends of the new bridge. Once in position above the old bridge, the extension brackets were used to support the new bridge on the abutments, as illustrated in Figure 3.13. Suspension rods were mounted between the new and old bridge to facilitate the dismantling of the old bridge, Figure 3.14. The new bridge was supported by bearings and jacks on the abutments while the extension brackets were removed, finally the bridge could be lower in to its right position, Figure 3.15. The total time for the bridge replacement was carried out during three days [7].

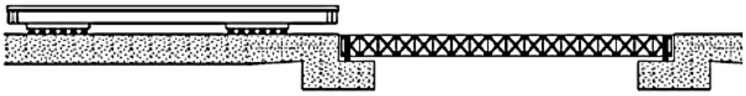

Figure 3.12. The new bridge arrives to the location of the construction site via the railway [7]

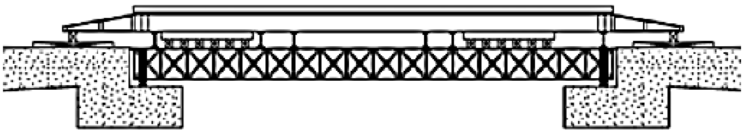

Figure 3.13. Brackets are mounted at the supports of the new bridge as well as suspension rods between the new and the old bridge [7]

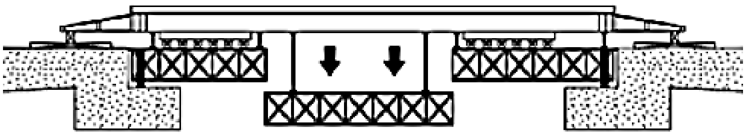

Figure 3.14. The old bridge is dismantled and lowered using the new bridge as a temporary structure [7]

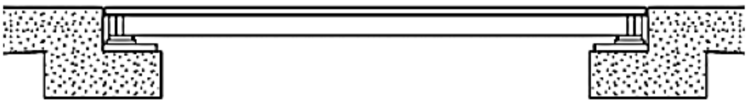

Figure 3.15. The new bridge is lowered to its final position [7]

3.6.3. Cantilever method

Launching gantries can also be used to build bridges with the balanced cantilever method (Figure 3.16). This method consists in assembling prefabricated segments outwards from the piers. Prestressing is applied to each segment as soon as it is installed in order to ensure that the cantilever structure is self-supporting. The assembly of the superstructure usually progresses from both sides of the pier at the same time so that the two cantilevers balance each other, although it can also be conducted from one pier the next one.

The method is suitable for the assembly of concrete box-girder bridges. It can be used for spans from less than 50 meters to 300 meters [15].

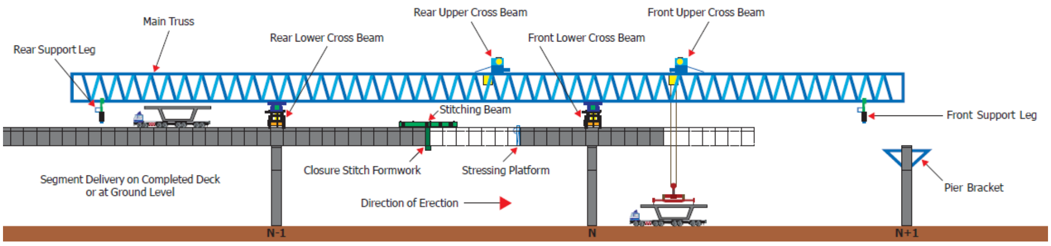

Figure 3.16. Balanced cantilever erection of prefabricated elements with launching gantry (Source: VSL)

Balanced cantilever erection of prefabricated bridge segments can also be realised using cranes (Figure 3.17) or strand jacks (Figure 3.18), as the structure is self-supporting. Both methods require the use of cranes under the bridge, at least to install the first elements on the piers and the lifting platform when strand jacks are used. Therefore they are only adapted in case there is a good accessibility under the bridge.

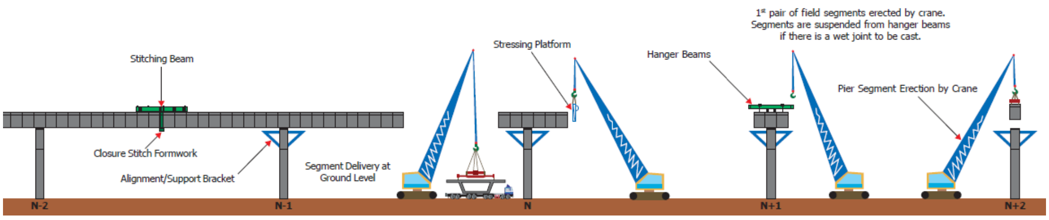

Figure 3.17. Balanced cantilever erection of prefabricated elements with cranes (Source: VSL)

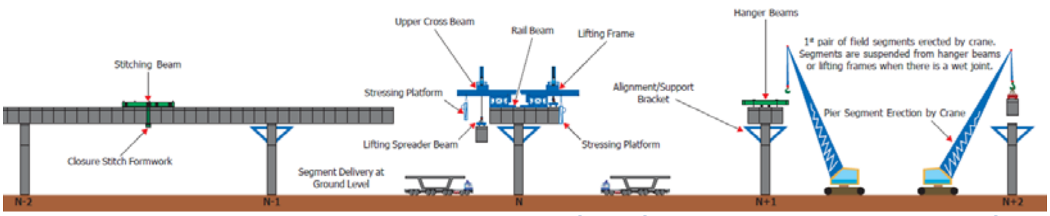

Figure 3.18. Balanced cantilever erection of prefabricated elements with lifting frames (Source: VSL)

4. Methods and processes

This chapter presents methods and processes used to accelerate the construction of bridges or to reduce the traffic disturbance during the course of the project. Some of the investigated projects have used traditional construction techniques but innovated ways to reduce the impact on the traffic. There is also solution that integrates the temporary structure into the final structure while traffic is running.

As previously described, accelerated bridge construction can often be achieved by prefabricating some parts of the bridge in order to minimise the amount of work performed on-site. In that case, the room for late changes and the flexibility on-site are less compared to traditional construction.

Prefabrication therefore calls for detailed planning and control to ensure that no unforeseen problem or mistake delay the on-site operations and jeopardize the whole project. Small deviations from the plan can have big consequences, especially when working with a tight schedule. For instance, the duration of a rail traffic stop required during the installation of prefabricated bridge elements over a railway is often planned long in advance and even a short delay could have significant economic consequences.

The requirements and most critical issues for the assembly process should be carefully identified and addressed in the planning stage. The transport, storage and installation of large and heavy prefabricated elements should be planned in such a way that all safety requirements are satisfied and disturbances to surroundings kept to a minimum, while minimizing the risks for unplanned disruption of works. Among others, the tolerances for the installation of the elements need to be appropriately defined and respected.

4.1. The Rotebro bridges

The project of Rotebro (2011 - 2015) consists of the replacement of the two existing parallel concrete bridges in Sollentuna, Sweden (see Figure 4.1). The bridges, which are 325 m in length, were built in 1962 and are replaced to be adapted to the increasing traffic volume.

Figure 4.1: Existing bridges at Rotebro (Source: NCC)

As illustrated in Figure 4.2, the bridges are located in an area with heavy traffic. More than 70 thousands motorists on the E4 Highway in Sweden cross the two bridges each day in both directions. Underneath the bridges, 600 trains pass the bridges per day. Therefore the biggest challenge was to carry out the demolition and construction work while allowing the highway and railway traffic to pass the site with as few disruptions as possible.

Figure 4.2. Main traffic routes around the Rotebro bridges (Source: Trafikverket)

The method adopted for the replacement of the two bridges was the alternative proposed by the contractor NCC. It is particularly noteworthy as it combines longitudinal and transversal launching of a 325 m bridge in order to make use of one of the new bridge in a temporary location. This method appeared to be the one minimizing both the construction costs and the traffic disturbances [30].

The method consists in building the first of the two new bridges next to the existing bridges. The bridge is longitudinally launched on temporary supports, in order not to affect the rail traffic under the bridge. When the bridge is completed, part of the traffic is rerouted to this bridge.

This makes it possible to dismantle the old bridge on the opposite side and to build the second new bridge at that same location. When this bridge is completed, the last of the old bridges in the middle is dismantled. The superstructure of the first new bridge is then laterally launched into its final position.

With this approach, two bridges with three lanes of circulation each can remain open to traffic during the whole course of the project, except during the three weeks of the lateral launching operation when all the traffic is rerouted to only one bridge with two lanes in each direction. The traffic disturbances are therefore reduced to a minimum by means of this construction method, thus leading to lower user delay costs.

4.2. Use of temporary girders in the permanent structure

In Japan during the replacement of a bridge on heavily trafficked line a method was developed to use a temporary structure that would become part of the final structural system.

First a temporary bridge was erected alongside the existing. Span lengths of the temporary girders were adapted to fit the ones of the existing four-span bridge. The train traffic was then redirected to the temporary bridge and the work of demolishing the original bridge viaduct could be carried out, Figure 4.3 [7].

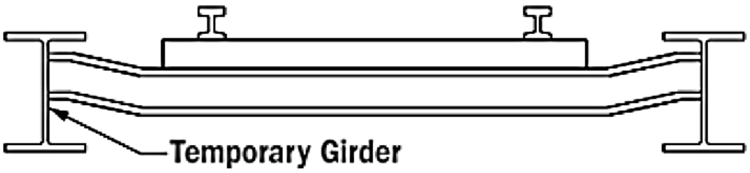

Figure 4.3. Section of temporary structure [7]

At the same time, the depth of the temporary girders was increased by adding girders below the temporary girders. Formwork was then added and concrete was cast in the forms while the bridge was in service, Figure 4.4 [7].

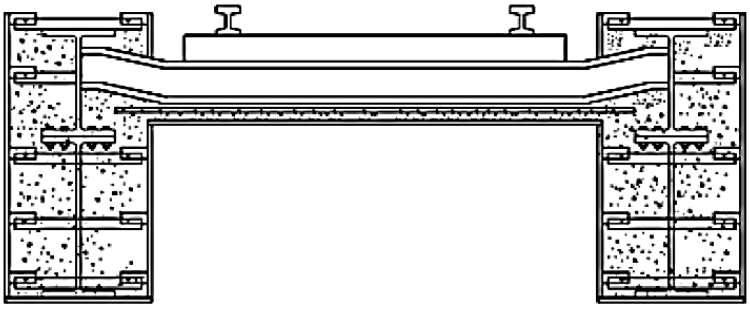

Figure 4.4. Final section of the bridge [7]

The completed bridge was then transversally launched to the position of the old bridge. Intermediate supports were then removed, so that the new bridge was transformed into a two-span bridge [7].

4.3. Replacement of bridge over the Åby River

In September 2012, the old railway bridge over the Åby River close to Piteå, Sweden, was replaced by a new bridge. The removal of the old bridge and the installation of the new bridge were planned during a train stop of 36 hours, from Saturday evening to Monday morning, when the traffic is the lowest. The operation was actually achieved two hours ahead of schedule.

From June to September 2012, the new bridge was assembled from prefabricated elements close to the old bridge and preparatory works were carried out. The activities on-site included:

- filling of a part of the River to build platforms for the launching operation, see Figure 4.5.a,
- installation of launching beams, see Figure 4.5.b,
- assembly of the superstructure of the new bridge, see Figure 4.5.c-d,
- preparation of the bearing surface at the abutments of the old bridge by wire sawing and hydrodemolition, see Figure 4.5.e,
- longitudinal launching of the new bridge over the river, see Figure 4.5.f. The new bridge was also laterally moved on transversal beams in order to liberate the launching beams over the river for the removal of the old bridge,

Afterwards, the traffic was stopped during a weekend in order to remove the old bridge and install the new one. This operation included the following steps:

- removal of rails and sleepers, see Figure 4.5.h,
- release of the bearings of the old bridge, see Figure 4.5.i,
- lifting of the old bridge with hydraulic jacks, see Figure 4.6.j,
- removal of the old bridge by lateral and longitudinal launching, see Figure 4.6.k,
- preparation of the abutments and drilling of holes for the new bearings, see Figure 4.6.l-m,
- lateral launching of the new bridge, see Figure 4.6.n,
- control and fine adjustment of the bridge position, see Figure 4.6.o,
- filling with crushed stones and compaction, see Figure 4.6.p-q,
- montage of the track see Figure 4.6.r,
- filling with macadam, see Figure 4.6.s,
- adjustment of the track, see Figure 4.6.t,

This example aims at showing that the replacement of a bridge requires many different activities both for preparation and during the replacement operation itself. Each of these activities can present potential risks for delaying the whole project. Therefore it is important to plan carefully the interaction between the different activities and that all the persons involved in the operation knows in advance exactly what they need to do.

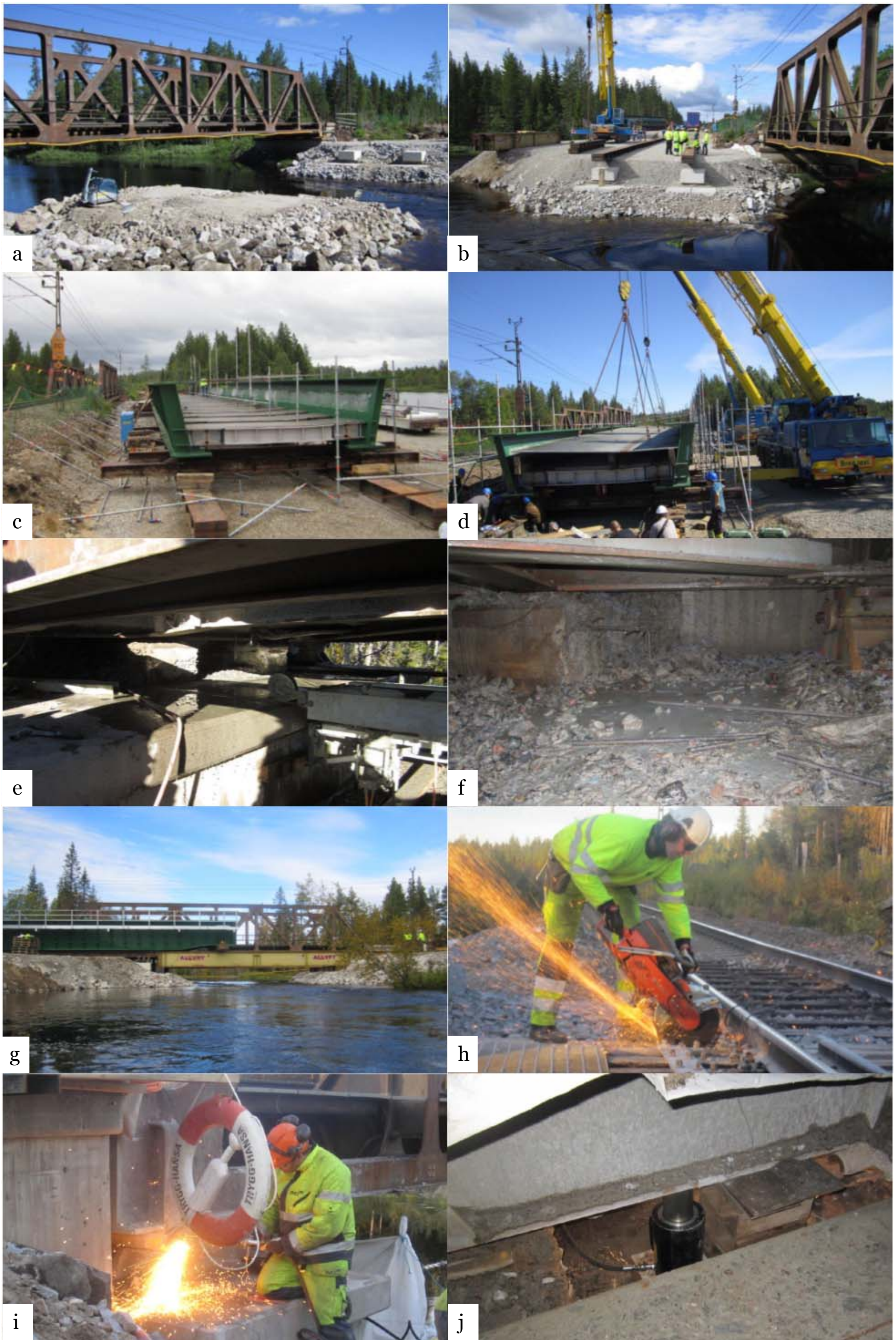

Figure 4.5. Building steps a-j for the replacement of the bridge over the Åby River [18]

Figure 4.6. Building steps k-t for the replacement of the bridge over the Åby River [18]

4.4. Motala bridge – Use of bridge wagons

The bridge over Motala Bay is located outside Motala, Sweden. It is a 620 m long composite bridge with a steel U-box girder with inclined struts and a concrete deck. The curved U-box girder was installed by longitudinal launching. The longest span of the bridge is 158 m in length. It is expected to be completed in 2013.

Two bridge wagons are used one after the other to accelerate and simplify the construction of the deck, see Figure 4.7.a-h. In the 1st wagon, reinforcement and concrete works are performed to build the middle part of the deck, which is 9 m in width. The 2nd wagon is used at the same time to extend previous portions of the deck on both sides over the inclined struts as well as to build the edge beams, therefore giving to the bridge its complete width of 21,2 m.

This method contributes to standardize the construction process for the deck. The bridge has been divided in 25 segments of 23,7 m each and the wagons are moved forward using hydraulic pushing systems on a weekly basis. The works to be conducted during each week can therefore be well-scheduled.

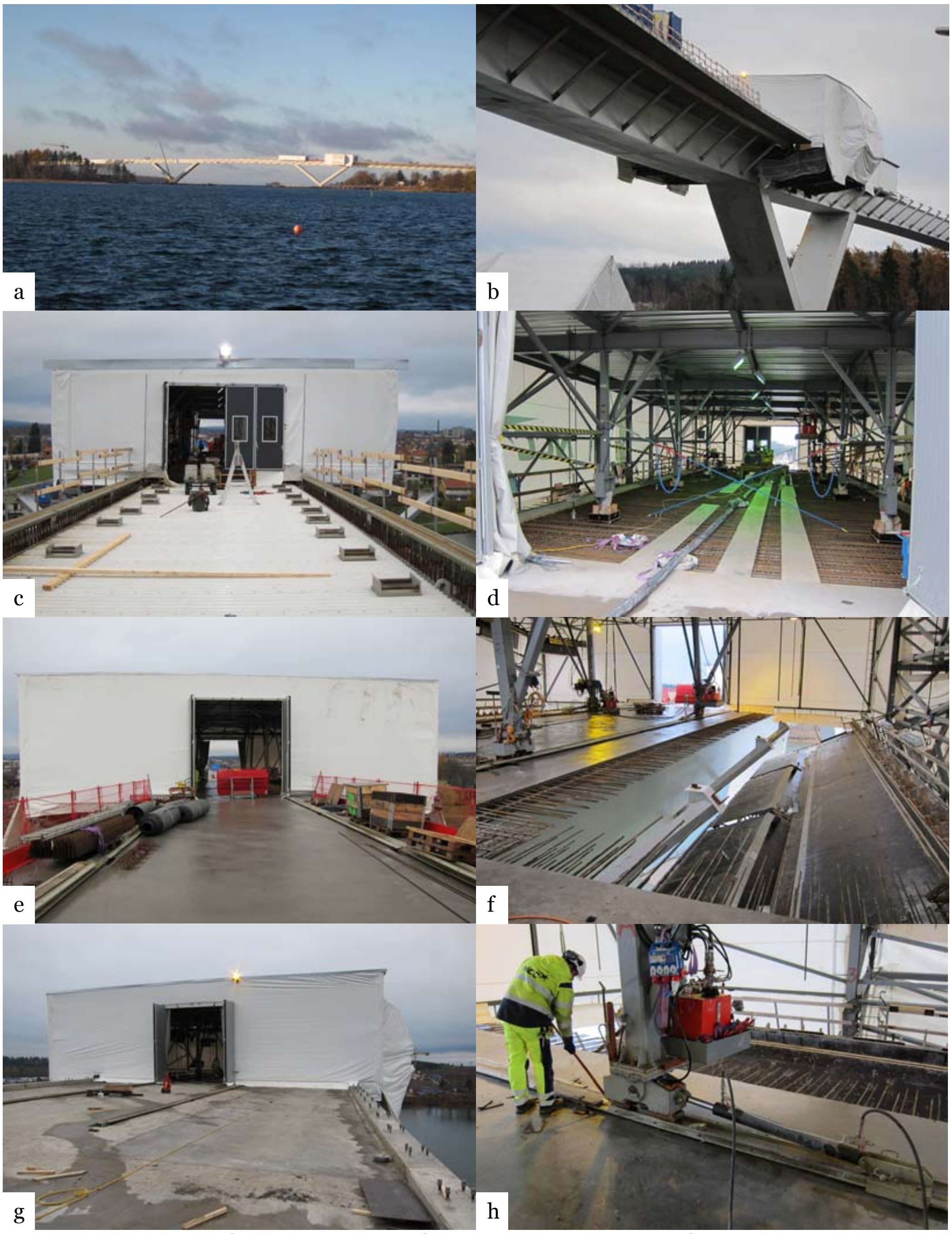

Figure 4.7. Use of bridge wagons for building the deck of the Motala Bridge: a) view of the bridge during construction, b) view of the two bridge wagons, c) view of the deck before the passage of the 1st wagon, d) reinforcement and concrete works in the 1st wagon, e) view of the deck before the passage of the 2nd wagon 2, f) in the 2nd wagon ,g)view of the deck after the passage of the 2nd wagon, h) hydraulic pushing system (Source: NCC)

4.5. NCC Montagebro

NCC Montagebro is a semi-prefabricated standardized bridge concept that is developed for fast and easy construction. It is suitable for passing water, railway or busy roads where traffic disruption must be minimized.

The substructure consists of on-site constructed foundations, plate structures and wings while the superstructure consists of prefabricated edge beams, beams and slabs, as explained in Figure 4.8.

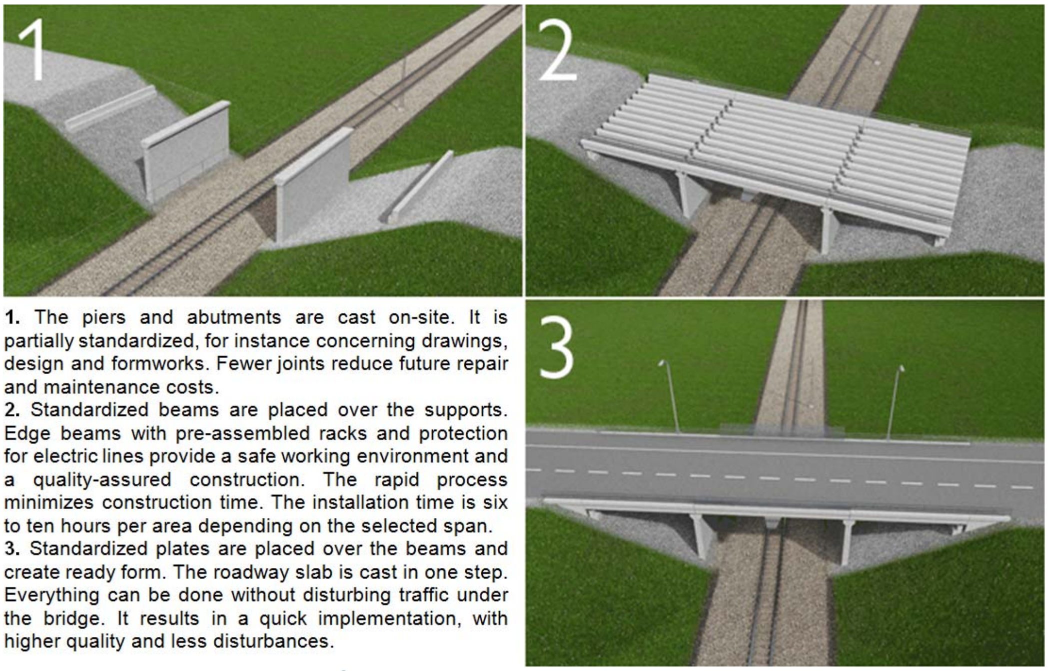

Figure 4.8. Building steps for NCC Montagebro (Source: NCC)

NCC Montagebro is not a new concept; it was first developed in the 1980's, and more than 13 bridges of this kind have been constructed since the 1990's, mostly over railways.

The continuous development of the concept in time allowed to standardize and refine it based on the experience from previous projects.

4.6. Persontågsviadukten

The railway bridges called Persontågsviadukten are two parallel railway bridges in the city centre of Gothenburg, Sweden, see Figure 4.9 and Figure 4.10. The bridges cross several railway lines as well as important roads and tram lines. In addition, 200 train passes on the bridges every day. The steel bridges were built in the 1930's.

The new bridge concept consists of steel and concrete part. The most accessible parts of the bridge were made of steel while the part of the bridge crossing the railway lines and the roads was made of concrete. The decision to use different materials was done to minimize maintenance (i.e. repainting) of the bridge parts crossing the tracks.

To ensure the removal of the existing bridges went as planned, hydraulic jacks were used to loosen each superstructure before lifting it with a crane. This is important because if the bridge is not totally released before the lift, the crane can become a “catapult” and the part lifted would become uncontrolled.

The good relation with the traffic controllers in charge of the planning of the railway and tram traffic appeared to be an essential factor of the success of the project. Due to the good communication and mutual understanding of each other’s requirements, it was possible to agree in advance on which tracks the trains and trams would pass. Therefore, the works on-site were simplified and the position of the crane used to lift off and on the bridge parts did not have to be changed more than necessary [31].

Figure 4.9. Aerial view of the Persontågsviadukten bridges (Source: Eniro)


Figure 4.10. Street view of the Persontågsviadukten bridges (Source: Eniro)

5. Concluding remarks

A wide range of prefabrication solutions and installation methods has been identified. Some of these techniques are well-known and extensively applied in some countries, while other techniques are more recent and have only been used in a few projects.

In the survey it has been found that the use of prefabricated elements or whole bridges that are produced off site and then transported to the bridge site for assembly costs less and gives a faster construction time than traditionally bridge construction. However to use prefabricated elements it can become less flexible than traditional bridge construction and also requires a good planning to have an even flow at the site.

Summarizing the literature survey and the interviews conducted during this project, it becomes evident that it is not just the actual construction of a bridge that has to be taken into consideration in a project, but also how the impact of the construction works can affect the traffic and the surrounding area as little as possible.

Many of the bridge projects today are situated in urban environment where the work areas are cramped or at railway lines where the traffic cannot be hindered. Unplanned disturbance to the traffic flow or to the environment can lead to big fines.

The success of a bridge project depends on good planning and requires a variety of tools, such as new techniques and innovative methods, to solve the obstacles that can arise.

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