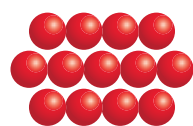


Precast & Prestressed Beam Bridges

Reinforced Earth® protective structures



TIERRA ARMADA
SUSTAINABLE TECHNOLOGY

Precast & Prestressed Beam Bridges

Tierra Armada, S.A. has significantly contributed to the development and consolidation of the Large Precast Elements Industrial Sector for Public Works during the last 15 years. Prefabrication is an advantageous alternative to traditional in situ construction procedures.

Advantages of precasting, when compared to other construction procedures, are multiple and well known:

- Better product quality:
 - Industrial manufacturing, with intense control and organization systems (CE marking)
 - Mastery and control in manufacturing of high initial and final concrete strength
 - Concrete steam curing process
 - Industrial control of manufacturing processes
 - Higher surface quality
- Lower structure construction costs:
 - Optimum design, calculation and construction of bridge decks
 - Utilization of High Performance Concrete and Prestressing techniques that allow for an optimum design of transversal deck sections, as well as minimizing material wastage.
 - Minimization and reliability of lead time for all structural components
 - Elimination of other in situ worksite process interferences
 - Possibility of working on several structures simultaneously
 - No dependence on climatic conditions
- Higher safety conditions for workers during construction
 - Utilization of large telescopic cranes, which allows for the elimination of scaffolding and working under highest safety conditions
- Environmental concerns:
 - Reduction of energy and material consumption, as well as reduction of pollutants
 - Higher structural durability
 - Minimum environmental impact on surroundings



Precast pre-stressed beams can be classified according to several criteria:

- **Transversal section:**
 - I Beams
 - TPP I beams (inverted I beams)
 - U beams

Although the type of beam is not important for drivers or pedestrians, other considerations allow us to decide which type to use. The most important considerations are the economical and the aesthetic ones.

- **Structural performance**, we have the following deck options:
 - Isostatic Bridge:
 - Single span bridge or multi-span bridge
 - With or without in situ compression slab continuity
 - Hyper-static bridge or Continuous bridge. Continuity is obtained by means of beam-to-beam joints (U beams) or by means of an in situ transversal beam (I beams)
- **Use of the bridges**, that is, the loads acting on the deck. The most common ones are:
 - Road bridges
 - Conventional train railroad bridges and high speed train railroad bridges
 - Pedestrian footbridges
 - Pipeline bridges (water, gas, etc.)

I Beams

The I beam is the simplest and most widely known element used for deck pre-casting. It is also the cheapest one, in all countries where the precasting industry is highly developed.

The general features are:

- Maximum span 50 m
- Height between 0.60 and 2.55 m
- Ratio Height/Span between 1/20 and 1/24 for road bridges, and 1/14 for railway bridges, depending on the type of train and its speed

The distance between beams and their heights is defined in the calculations carried out by Tierra Armada, S.A., according to the loads acting on the deck and the geometric limitations of the structure, that is, clearance under beams, distance between piers, etc.

Although optimum utilization of these beams is obtained on isostatic decks, it is also possible to create a continuous deck by means of an in situ transversal beam on each group of piers.

Isostatic decks are usually designed with in situ compression continuity slab, which allows for separating road expansion joints and increased driver comfort. The distance between joints should not be higher than 120 meters.

The span and width of the deck are the basic data given by our clients. According to them, Tierra Armada, S.A. gives the economically and technically optimum solutions.

The catalogue of beams presented in the following paragraphs is the final result of many years of experience in designing, calculating and manufacturing hundreds of structures.

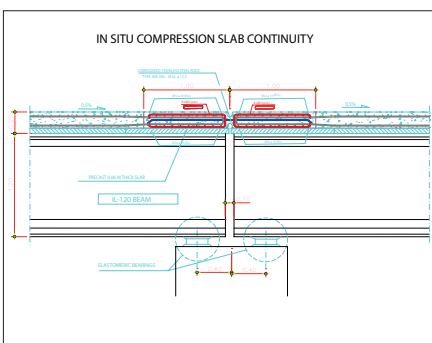
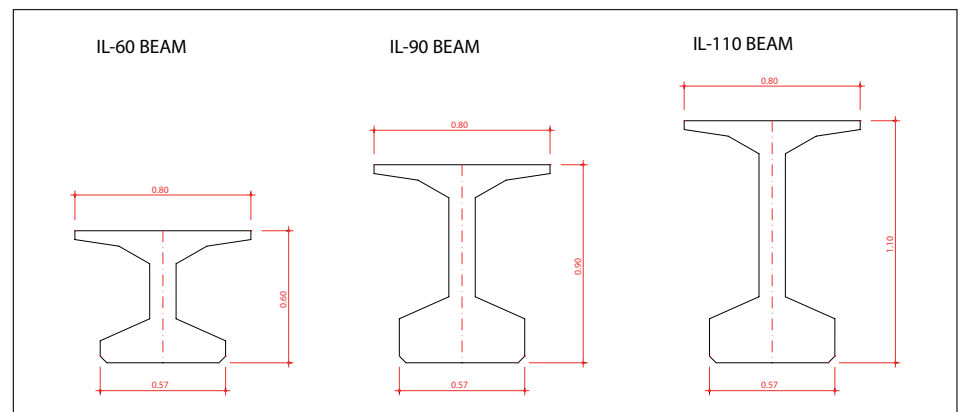
2.1 IL Series

It includes our smallest I beams. The main features are:

- Height between 0.60 and 1.10 m
- Span between 8 and 24 m
- Upper wing width 0.80 m
- Lower wing width: 0.57 m



Bridge over Madrid-Guadalajara Railway (SPAIN)
4 IL-110 beams per span



Pass under M-503 Highway (Madrid - SPAIN) - 8 IL-100 beams per span, supported by buttressed panel abutments



A-67 Highway (Palencia - SPAIN). Section: Alar del Rey – Puebla de San Vicente - Viaduct 2.3
Solution: 5 IP-155 beams per span

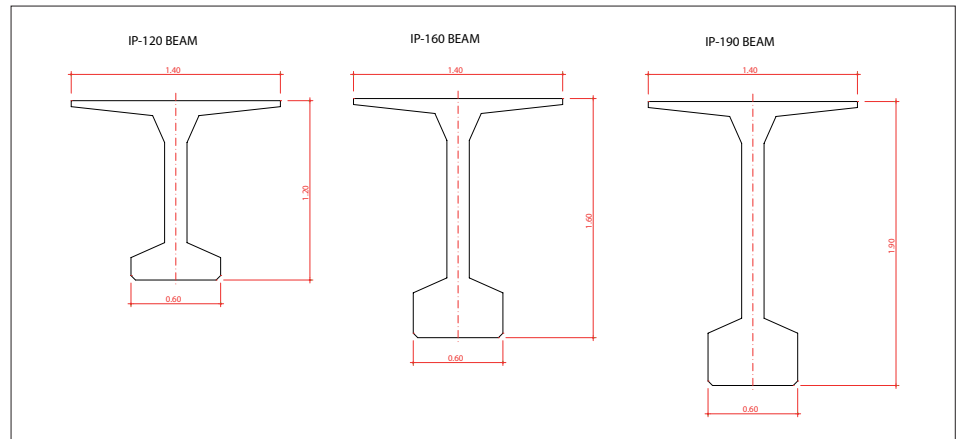


A-67 Highway (Palencia - SPAIN) - Section: Alar del Rey – Puebla de San Vicente - Viaduct 2.9
Solution: 5 IP-200 beams per span

2.2 Medium Height IP Series

Includes the medium length and height I beams. The main features are:

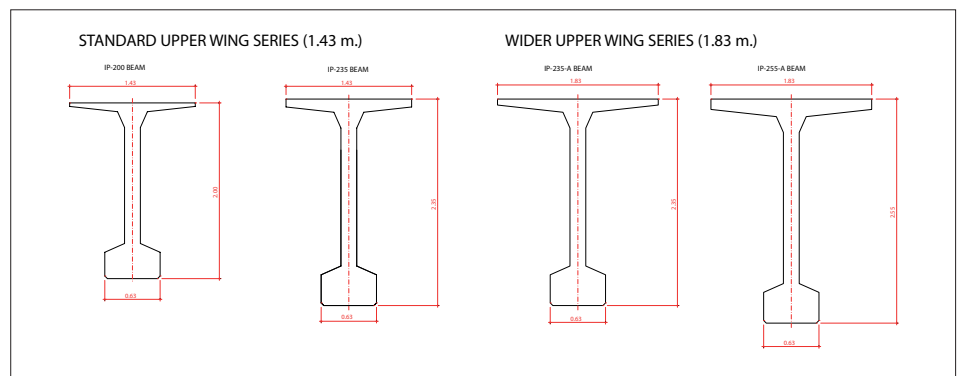
- Height between 1.20 and 1.90 m
- Span between 18 and 38 m
- Upper wing width 1.40 m
- Lower wing width: 0.60 m



2.3 Maximum Height IP Series

Includes our heaviest I beams, used for the longest spans. The main features are:

- Height between 2.00 and 2.55 m
- Span between 32 and 50 m
- Upper wing width 1.40 m or 1.43 m
- Lower wing width: 0.63 m



2.4 Derived Series

Structure features are not always standard. It may be necessary to calculate decks with exceptional traffic loads, or exceptional earth layer thicknesses on the deck. Sometimes, a minimum clearance is mandatory and, consequently, an extremely thin deck must be designed.

In these situations, a customized technical solution must be designed and manufactured. Tierra Armada, S.A. is capable of delivering these solutions due to both the highly experienced civil engineers and the flexible means of production available at its factories.

It is possible to obtain beams different from the standard measures presented in the above paragraphs, lighter or heavier beams, with the same height, depending on the structural geometry and load demands.

The most common changes are:

- Increasing the thickness of the upper wing, 5 cm common. This thickness allows us to graduate the height of the beams every 0.05 meters in all cases
- Increasing thickness of the beam web, more commonly 3 or 6 cm
- Mixed of upper and lower wing geometries, different from the standard ones

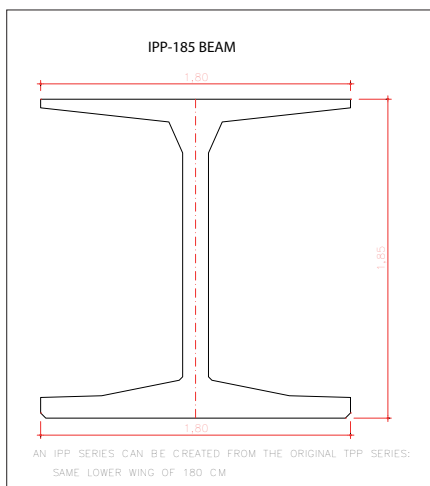
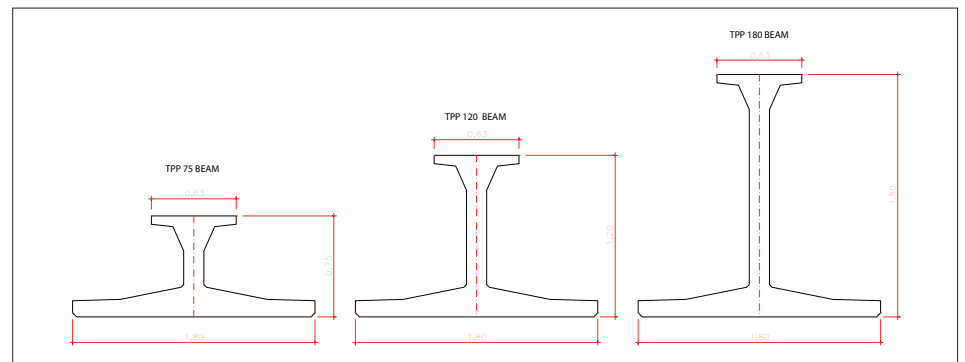
Inverted I Beams

Inverted I beams are necessary if, due to aesthetic reasons in overpasses, the inferior deck surface must be flat, or due to functional reasons, such as protection against accidental fire in tunnels. In those decks, the beam lower wings are in contact.

3.1 TPP Series. Flat deck:

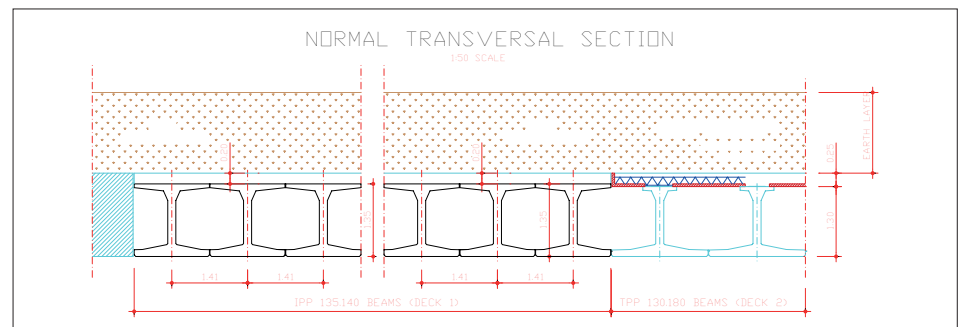
The main features are:

- Height between 0.75 and 1.85 m
- Maximum approximate span: 40 m
- Upper wing width: 0.63 m
- Lower wing width: between 1.20 and 1.80 m, equal to the distance between beams



3.2 IPP Series. Flat deck:

These beams are equivalent to the previous series, but both wings have the same width.



These beams were widely and successfully used in the subterranean reconstruction of Madrid's first ring highway (M-30), as well as in the structures over the TF-1 highway in San Isidro (Tenerife - Canary Islands - SPAIN).



Subterranean reconstruction of Madrid's first ring highway (M-30)



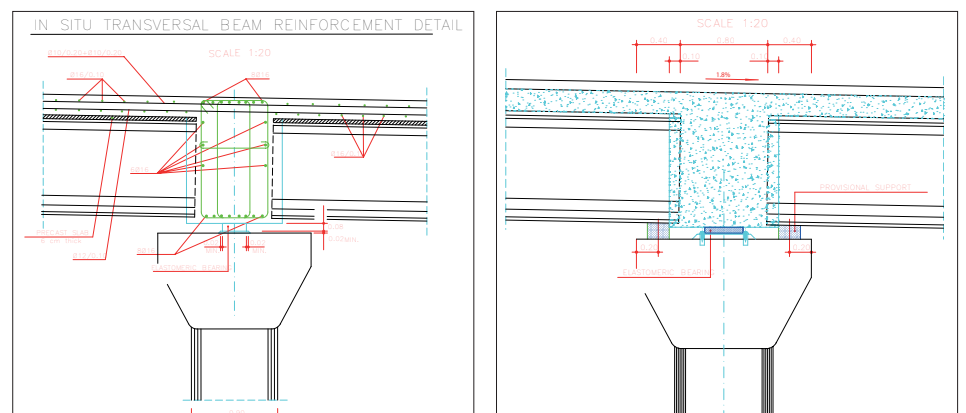
Bridge over the TF-1 Highway, Tenerife (Canary Islands - SPAIN) - 4 TPP 165.180 beams per span

I beams for hyper-static decks

Optimum performance of the prestressing cables is obtained when the deck of the structure is isostatic; in this case, the bending stresses, caused by dead and live loads, are directly absorbed and supported by these cables. However, it is perfectly possible to assure total deck continuity and obtain a hyper-static structure by means of an in situ transversal beam on every row of piers, which joins all I beams ends.



IP-3. Scut Interior North (PORTUGAL) - Construction of an in situ transversal beam, in an hyper-static I beam deck



I beams for seismic regions



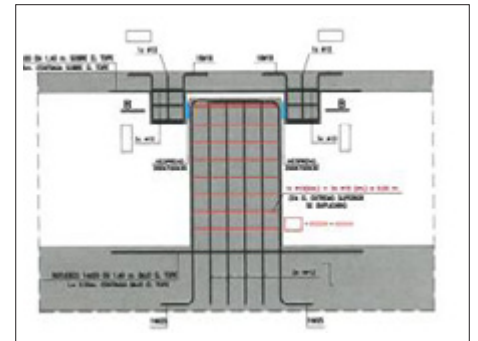
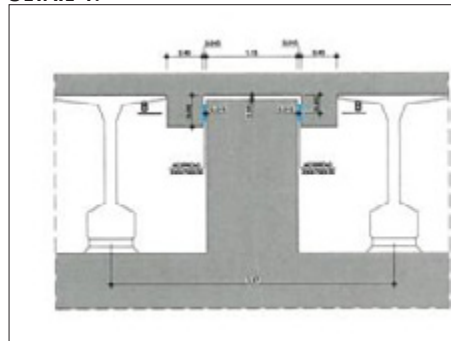
Seismic diaphragms between I beams to impede transversal movement and deck offset

Special preventive measures must be taken in regions with seismic risk, in order to assure structural durability throughout the structure's lifetime.

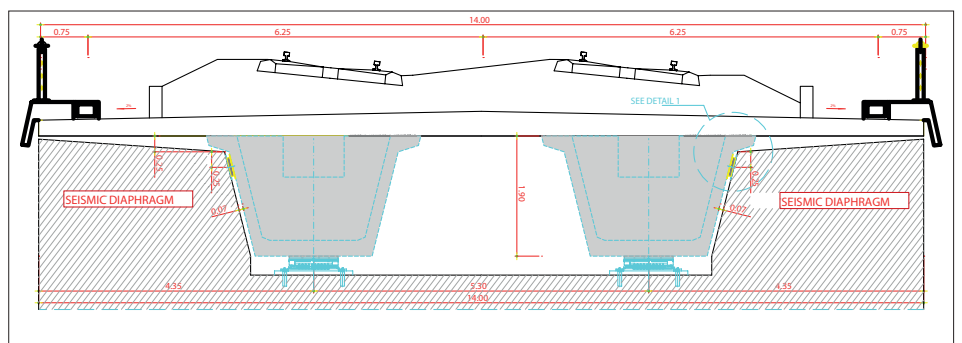
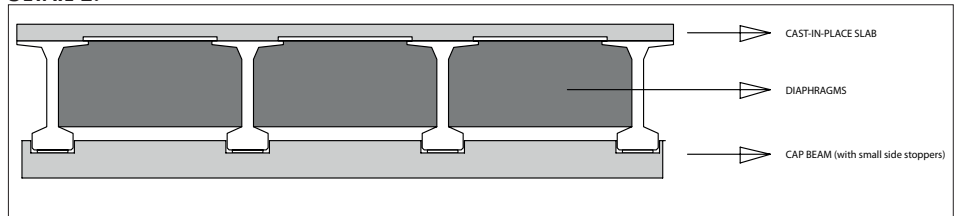
These preventive measures are:

- Constraint to rotation of deck in skewed bridges. Abutments and piers should be built perpendicular to bridge axis.
 - Guarantee integrity of precast beams by impeding their transversal movement during the seismic excitation. There are two possible solutions:
 - Construction of an in situ transversal beam to join all precast beams, as seen in the previous paragraph
 - Construction of in situ transversal elements:
 - Overhanging buttresses joined to the lower loading beam, with side stoppers at the top (see detail 1)
 - Diaphragms between the beams (see detail 2)
- In both alternatives, the elements should have the same height than the beam.

DETAIL 1:



DETAIL 2:



High speed train line Madrid - Alicante (SPAIN) - Viaduct over La Encina-Caudete Railway
Seismic diaphragms at one side of U beams to impede transversal movement and deck offset

Pergola bridges

Pergolas are the most common typology used in split level junctions with a small skew angle, for the distances to be spanned in this solution are shorter than in any other. The minimum span is defined by the inferior platform road width. Pergolas are widely used both for high speed rail crossings and for road crossings. Precast I beam solutions are the most commonly used typology, and are specially appropriate when traffic must be maintained, as the weight of each element is minimum and can be erected with light cranes.



Nueva Ronda Oeste de Málaga (SPAIN) - 2 Pergola bridges



Connection from Torrejón de Ardoz (MADRID - SPAIN) to A-2 highway (Madrid - Barcelona)

U beams

U beams were designed as an attempt to precast the in situ U-shaped section bridges. The first bridges with these beams were built in the 70s and they were 7 m wide. These beams became stronger and heavier to facilitate the construction of wider bridges, hyper-static bridges and curved bridges.

Advantages of U-beams, compared to I-beams are:

- Smaller beam height, for the same span
- Lintel beam over the piers is not necessary
- Smaller number of beams to manufacture, transport and assemble for the same bridge
- Better performance for Railway bridges

The disadvantages are:

- Overly heavy beams, with increased transportation difficulties
- Calculation problems:
 - Does not adapt well to skewed bridges
 - Precast slab overhang calculation is problematic
- May have higher initial cost

Tierra Armada S.A. has designed three series of U-beams, all of them have a height between 0.90m and 2.60m:

- **Narrow series**, lower width 1.85 m, for decks with several beams per span.
- **Medium series**, lower width 2.60 m, for decks with several beams per span or mono-beam decks
- **Wide series**, lower width 3.20 m, for mono-beam decks

With this type of beam, spans of more than 40 m of span have been constructed, both in isostatic road bridges and on high speed isostatic train bridges. If the deck is hyper-static, spans between 60 and 90 meters can be designed.

Curved viaducts can be designed in one of the following two ways:

- By means of a polygonal line made of straight U mono-beams with bevelled endings
- By means of a curved U mono-beam



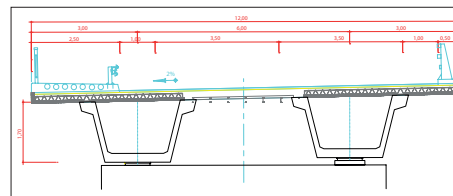
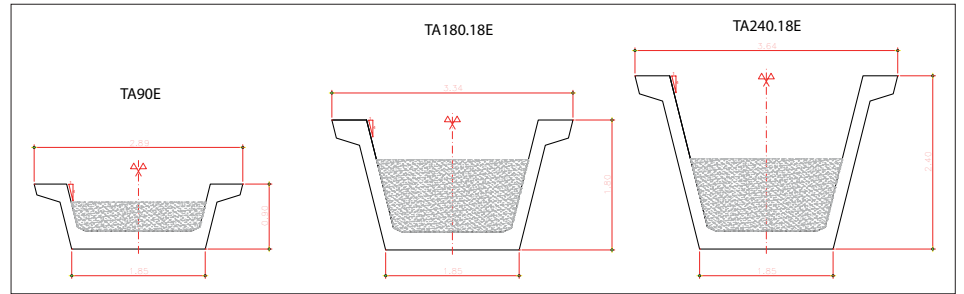
High Speed Train Viaduct - Section Mocejón - Toledo (SPAIN)
Spans length: 36 m - 2 narrow TA-260 beams per span



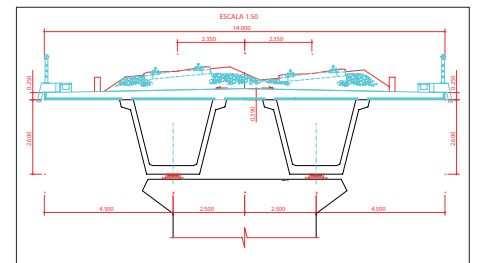
High Speed Train Viaduct - Section Mocejón - Toledo (SPAIN) - Spans length: 36 m - 2 narrow TA-260 beams per span

7.1 Narrow series:

- Height between 0.90 and 2.60 m
- Maximum span 40 m
- Lower wing width: 1.85 m
- Usual distance between beams 6.0 m



Usual transversal section for highway overpasses



Usual transversal section for high speed train (AVE) viaducts-mono-beams



M-203 Highway - Viaduct over M-206 road (Madrid) - 3 narrow beams (1.50 m high) per span, supported by circular piers



M-503 Highway - Viaduct over Aulencia river (Madrid - SPAIN) - 2 narrow TA-110 beams per span, supported by circular piers

7.2 Medium series:

- Height between 0.90 and 2.60 m
- Maximum span 40 m, height 2.20 m
- Lower wing width: 2.60 m.
- Normal mono-beam deck width: 7 a 9 m

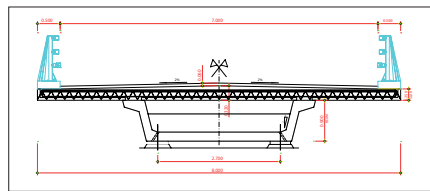
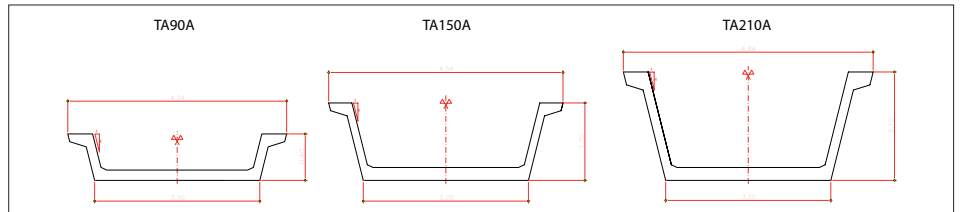
For wider decks, using precast buttresses to partially support the compression slab is necessary.

7.3 Wide series or Mono-beam series:

- Height between 0.90 and 2.60 m
- Maximum span 40 m, height 2.10 m
- Lower wing width: 3.20 m.
- Normal mono-beam deck width: 9 a 12 m

For wider decks, using precast buttresses to partially support the compression slab is necessary

For any width, it is highly recommended that the in situ compression slab be cast in two phases, in order to minimize deformation at the edge of the slab.



A-12 Highway (Camino de Santiago Highway) - Herviás-Grañón section (La Rioja - SPAIN) - Overpass with wide TA-90A mono-beam, supported by palm shaped precast piers



M-503 highway - Viaduct over Guadarrama river (Madrid - SPAIN) - Curved alignment solved with straight wide 1.50 m high U mono-beams



Curved highway connection, from M-45 to A-2 (Madrid - SPAIN), solved with a curved wide 1.50 m high U mono-beam



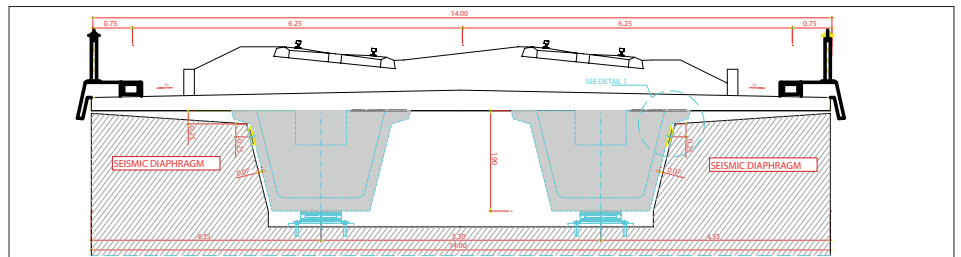
Highway overpass: M-45 over A-4 (Madrid - SPAIN), solved with a wide 1.50 m high U mono-beam
Deck width = 15 m - The in situ compression slab is supported at its edges by precast buttresses

U beams for hyper-static decks

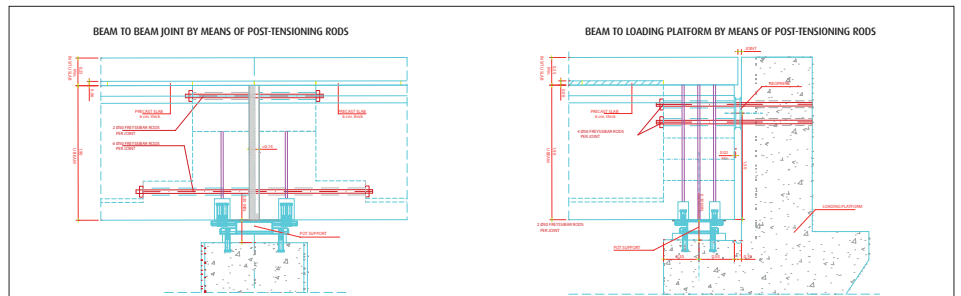
Optimum performance of the prestressing cables is obtained when the deck structure is isostatic; in this case, the bending stresses, caused by dead and live loads, are directly absorbed and supported by these cables. However, it is perfectly possible to assure a total deck continuity and obtain a hyper-static structure.

It is necessary to create beam-to-beam joints, by means of 50 mm diameter post-tensioning rods, in order to assure perfect transmission of stresses throughout the different spans. In order to absorb the negative bending moments on top of every row of piers, some additional passive and active reinforcement rods must be later inserted into the in situ compression slab.

Beam-to-beam joints are carried out on piers provided that span length is under 40 m. For longer spans, beam weight does not allow for that, and it is mandatory to join beams at intermediate points along the span. In these situations, non uniform height U beams must be designed on piers.



High speed train line Madrid – Alicante (SPAIN) - Viaduct over La Encina-Caudete Railway
Spans length: 17 – 29 – 17 - Beam height: 1.90 m



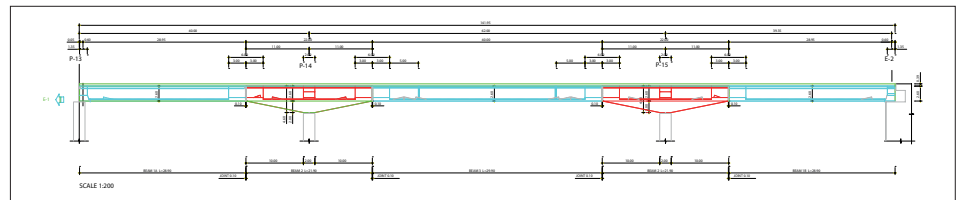
High speed train line Madrid – Barcelona (SPAIN) - Spans length: 30 m - Beam height: 1.90 m - Beam-to-beam joint detail

Non uniform height U Beams

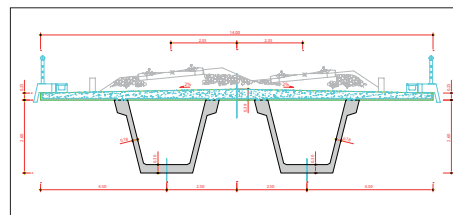
Variable height U beams can also be made. A parabolic transition between the minimum and maximum heights is possible, although a straight transition is the most common solution. These solutions have been widely used on large span structures, allowing for an aesthetic appearance similar to that of the cantilever bridges.

In very long spans, the usual precast solution is to combine non uniform height beams, supported directly by the piers, with uniform height beams; both types of beams are joined by post-tensioning rods which form a continuous span bridge. Finally, post compression slab tensioning is necessary on top of every row of piers. Span lengths of more than 60 meters have been achieved through this type of design.

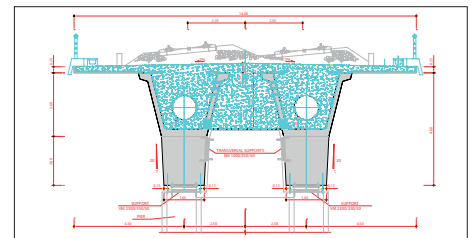
An example of this is the Railroad Viaduct over the A-31 Highway, part of the Monóvar – Novelda section of the Madrid – Alicante AVE line, where a hyper-static 3 span structure was designed. The lengths of the spans were 40-62-40, and non uniform height U beams were used: 2.60m at the middle of the span and 4.60m on top of the pier (see illustration below)



Baladrés Viaduct - Hyperstatic stretch over A-31 Highway (Alicante) - Spans length: 40 - 62 - 40 - Beam height: 2.60 m - 4.60 m



Baladrés Viaduct - Transversal section at the middle of the span - Beam height 2.60 m



Baladrés Viaduct - Transversal section on top of the piers
Beam height 4.60 m



Baladrés Viaduct - Hyperstatic section over A-31 Highway (Alicante) - Spans length: 40 - 62 - 40 - Beam height: 2.60 m - 4.60 m

Other structural elements of the bridge

Today the precast industry is prepared to manufacture and supply all the elements of a bridge, that is, piers, lintels, abutments, built-in formwork slabs, etc.

10.1 Precast slabs

Precast decks are made of beams and slabs. Precast slabs cover the whole surface of the deck and support the weight of cast-in-place concrete.

There are two types of precast slabs:

- **Standard slabs:** 0.06 or 0.07 m thick, are made of reinforced and/or prestressed concrete. They usually cover the surface between beam wings, at I beam decks and U beam decks.
- **Truss slabs:** 0.06 or 0.07 m thick, much longer than standard slabs. They are always made of bend resistant reinforced concrete, with an overhang beyond the U beam of up to 3 meters.



High Speed Train Viaduct - Section Mocejón - Toledo (SPAIN) - Truss slabs

10.2 Precast piers and lintels

Tierra Armada, S.A. is capable of pre-casting all types of piers. The most usual ones are:

- **Pier-lintel simple portico:** made up of two or more piers that support a lintel. Piers can have a square, circular, hexagonal or octagonal transversal section. Lintels can be rectangular or trapezoidal. They are used to support several I beam decks.
- **Piers with bell capital:** usually square or circular transversal section, as described above, but terminating in an inverted bell shaped capital which directly supports the I beam without a lintel. These types of piers are widely used on several U beam decks, but can also be used for I beam decks.
- **Palm shaped piers:** used for U mono-beam decks. The upper part of the pier widens to bear the double support beam.
- **Hollow piers:** usually with rectangular transversal sections, and very large heights. A 30 m high pier has been constructed with this section in Adeje (Tenerife, Canary Islands, SPAIN), to support gas and water pipelines on the deck.



M-224 Road - Structure over high speed line railway in Torres de la Alameda (Madrid)
3 span deck, 4 IP-130 beams per span, supported by a portico, made up of 3 octagonal piers (9 m high) plus a lintel



Viaduct over the Combos river, in Arroyomolinos (Madrid - SPAIN)
6 span deck, 6 IP-165 beams per span, supported by square piers (9 m high) with bell capital, without lintel



A-12 Highway (Camino de Santiago Highway) Hervias-Grañon section (La Rioja - SPAIN)
Deck supported by palm shaped precast piers



Water and gas pipeline bridge in Adeje (Tenerife, Canary Islands - SPAIN) - Hollow piers; transversal section 1.50x2.20; height 30.0 m

10.3 Precast abutments

Tierra Armada, S.A. offers three classic precast solutions for bridge abutment construction:

- **Reinforced earth abutments:** The in situ floating load-bearing beam transmits the deck loads directly to the reinforced earth soil behind the wall. In some cases, the loads may be transmitted to piles, rather than to the reinforced earth soil. By tiering the reinforced earth walls, heights of more than 20 m can be reached. A decorative finish may be applied to the panels in order to enhance the aesthetic character.
- **Buttressed panels abutments:** The buttressed 2.40 m wide panels are crowned by an in situ load-bearing beam which supports the girders. The panels are anchored in a continuous, cast-in-place foundation. This solution is used on high bearing capacity sites, and allows for the creation of up to 15 m high abutments.
- **Abutment pile coverings:** In some instances, rectangular concrete panels with a thickness of 10 to 15 cm, resting on the ground and affixed to the load-bearing beam, greatly enhance the aesthetic appearance of the structure.



Pass under Corredor del Nalón road. Sotrondio – Barredos section (ASTURIAS – SPAIN)
Reinforced earth abutment, supporting U beams



Reinforced earth abutment, supporting I beams



M-501 Road duplication (Madrid – SPAIN) - Buttressed panel abutment

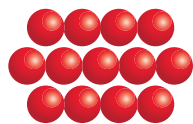


M-50 Highway (Madrid – SPAIN) - Abutment pile coverings



Our goal is to create, design and supply innovative technologies to the civil engineering industry. Above all we recognize our professional, civil and engineering responsibility to provide economical and practical solutions with a strong commitment to excellence in design, service and public welfare.

Sustainable Technology



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