The present invention relates to a formwork for concreting the inner lining of tunnels, made up of a resistant structure formed by two polygonal rings, perpendicular to the axis of the tunnel, made up of a variable number of ribs (1) articulated to one another and joined by a telescopic prop (4) which allows varying the angle they form in order to thus vary the curvature of the perimeter ring, such that by also varying the number of ribs (1) it is possible to adapt it to any measurement and configuration of the tunnel (t) to be constructed; a series of secondary ribs (2) externally defining a curvature (21) in accordance with each area or sector of tunnel in which it is assembled; and a series of flexible steel sheets (3) which adopts the radius of curvature suitable for the area or sector of tunnel to be constructed and makes up the skin of the formwork on a surface, having the length of the formwork and the width corresponding to a sector of tunnel, defined by one of the intermediate parts (2) supporting it and by the rib or ribs (1) forming the inner structural rings.
Description

Object of the Invention

[0001] As indicated by the title, the present invention relates to formwork for concreting the inner lining of a tunnel, which is made up of a series of panels forming a ring defining the vault, the sides and the corners of the base of the tunnel. The set of the formwork is assembled on a carriage which is moved along the longitudinal axis of the tunnel, from one course to the next, supported on railway tracks placed previously or on the invert of the tunnel. The formwork panels are in turn provided with articulated connections which allow inwardly collapsing the panels forming the small side walls and the sides of the tunnel for stripping and being able to move the formwork to the next placement, before positioning it and the subsequent concreting of the next course.

Background of the Invention

[0002] Currently there are formworks of the type described in the preceding paragraph for specific tunnels; this means that as the panels externally define a ring with a radius and configuration in accordance with only the particular tunnel, its cannot be used for other tunnels unless they are identical. Therefore, a formwork must be manufactured for each construction job, there currently not being a universal formwork system which can be applied to any tunnel, thus neither is there the possibility of hiring formworks of this type which the constructor or installer can adapt it to each particular construction job, increasing the cost (considerably) of concreting the inner lining of the tunnels as well as being a delay to the start of the construction job since the specific formwork must be manufactured beforehand.

Description of the Invention

[0003] The formwork of the invention provides a series of panels forming an inner ring of the tunnel, formed by a variable number of panels, each externally having an arch on the outside in accordance with the specific tunnel to be concreted. This perimeter ring perpendicular to the axis of the tunnel is defined by a resistant structure made up of a variable number of ribs which are articulated to one another by the outer side edges, located closer to the wall of the tunnel, while the two inner edges of every two annexed ribs are related to one another by a telescopic prop which allows varying the angle formed by the two consecutive ribs between which it is located, and consequently varying the curvature of the perimeter ring in each sector of the tunnel. Therefore, by varying the number of ribs, it is possible to form a polygonal ring, inside the formwork, adaptable to any measurement and configuration of the tunnel to be constructed.

[0004] Another intermediate part or secondary rib is located on each of these primary ribs, said intermediate part or secondary rib externally defining a curvature in accordance with each area or sector of tunnel in which it is assembled and making up the supporting means for the sheet metal defining the skin of the formwork.

[0005] These intermediate parts or secondary ribs are elements with a changeable structure, formed by means of articulated and movable plates which allow modifying the outer curvature of each part for adapting it to the specific curvature of each sector of the tunnel, whereby they are also universal elements which can be adapted to any radius of curvature. Another alternative for these secondary ribs is constructing elements with the curvature in accordance with each sector of each particular tunnel; in which case these would be the only parts which would have to be constructed for each construction job, the remaining elements of the system being universal and reusable for successive construction jobs.

[0006] The skin of the formwork is made up of flexible steel plates, each of which is assembled or formed with the radius of curvature adjusted to the area or sector of tunnel to be constructed, i.e., with the length of the formwork and the width corresponding to a sector of tunnel, defined by one of the intermediate parts supporting it and by the main rib or ribs forming the inner structural rings.

[0007] The set of panels making up the formwork are grouped and structured in the following sections:

a) An upper section defining the vault of the tunnel made up of a variable number of keystone panels, which are symmetrically assembled at both sides of the axis of the tunnel, forming the upper part of the formwork and which, once assembled in position and stiffened with the appropriate angles, are all braced at the bottom with one prop per rib relating the two end ribs through the inside of the formwork, while at the same time allowing elevating and placing it on the formwork driving carriage;

b) Respective side sections made up of a variable number of side wall panels which, once joined to one another, are assembled in the respective sides of the vault section through an articulation located on the inner face, operated by means of a cylinder or similar means, allowing the collapsing of the lower end towards the inside of the tunnel in order to facilitate the transport and stripping operations. During the concreting operation this articulation is stiffened by means of a telescopic prop; and

c) Respective panels located below the side sections forming the small side walls or side closures of the tunnel with the lower footings, which articulate by collapsing towards the inside of the tunnel for facilitating the transport and stripping operations, being operated by a cylinder or similar means. This articulation is also stiffened during the concreting.

[0008] A transport carriage which serves as a support structure for the formwork has been designed for moving the set of the formwork between placements, which is
formed by respective main gantiers located in the plane normal to the layout of the tunnel, joined by means of longitudinal tie beams. This carriage rolls on tracks arranged on the site on the starting footings of the tunnel or on a temporary footing in the invert. This carriage also has a hydraulic system for performing all the operations during the normal work cycle: translating, horizontal shifting, moving skirts, elevating and lowering, (and even being able to change the inner geometry of the tunnel, if it is modified at some point).

[0009] For performing the formwork/stripping operations the carriage has cylinders which retract the side panels from the side walls of the tunnel, collapsing them with respect to the intermediate articulations after retracting or collapsing the small side walls of the base. The keystone is formworked/stripped by operating the hydraulic cylinders of the carriage legs which lower or elevate the keystone panels defining the vault of the tunnel. Next, the shifting is carried out consisting of the relative horizontal movement between the carriage rolling on a fixed position (the tracks) and the formwork for allowing the horizontal adjustments of the latter.

Description of the Drawings

[0010] To complement the description which is being made and for the purpose of aiding to better understand the features of the invention, a set of drawings is attached to the present specification in which the following has been depicted with an illustrative and non-limiting character:

- Figure 1 shows a schematic front elevational view of three formworks (A-B-C) with different radii formed by universal and reusable panels (P) for forming several tunnels, with different radii and configurations.
- Figure 2 depicts a detailed section of a formwork with these features in the operating position, i.e., before concreting the tunnel.
- Figures 3 to 6 schematically depict the assembly sequence of a panel of the type depicted in Figure 12, with its three basic elements: main rib (1), secondary rib (2) and sheet metal or formwork skin (3).
- Figures 7 to 11 show the assembly sequence of the different panels forming a formwork on the corresponding transport carriage (c).
- Figures 12 and 13 depict respective sectional views of two different constructive solutions for formwork panels, both carried out according to the invention.
- Figures 14 to 16 schematically depict the assembly sequence of a panel of the type depicted in Figure 13.
- Figure 17 corresponds with Figure 2 when the formwork is in the stripping position, before being moved to the next placement of the tunnel to be concreted.

Preferred Embodiment of the invention

[0011] As seen in the mentioned figures, the invention relates to a special metal formwork which reproduces the inner geometry of the specific tunnel, therefore being able to adapt to the geometries of any tunnel. To that end, it is made up of a determined number of panels (P) joined by means of articulations and telescopic props which are immobilised before and during the concreting process, internally defining a resistant polygonal ring and externally defining a radius of curvature in accordance with each area of the tunnel to be concreted.

[0012] The panels forming the tunnel formwork are of three types differentiated by the different areas of the tunnel: keystone panels (Pc), side wall panels or skirts (Ph) and small side walls (Pf).

[0013] The keystone panels (Pc) are located in the upper area of the formwork and therefore form the vault of the tunnel. There are arranged on said panels gates for pouring the concrete, quick tie-back plates for surface vibrators, windows for inspection during the concreting process and attachments on which the keystone props are tied, assembled above them are the platform for concreting under the keystone.

[0014] The keystone panels are located symmetrically in the upper part of the formwork at both sides of the axis of the tunnel, starting from the central panel, joined to each other longitudinally by means of a lower prop (5) which is fixed in the gantry (c1) of the transport carriage (c), until entirely completing the formwork of the vault (Figures 7 to 9).

[0015] The side wall panels (Ph) are located on the sides of the tunnel, they are curved metal panels having the same structure as the keystone panels and the small side walls. Lugs for the concreting brackets, inspection and concreting windows, quick tie-back plates for surface vibration and the draught profiles for operating the hydraulic operating cylinders are arranged in said panels.

[0016] The side wall panels (Ph) are joined to the keystone panels at their high part through an articulation which allows rotation for the stripping and transport operations as a result of a cylinder (c3) joined and operated from the transport carriage (c). The side wall panels are joined in the lower portion with the small side wall panels by means of rotating lugs and also by a cylinder (7) which is connected with the hydraulic circuit of the carriage for operating it during the formwork/stripping operations.

[0017] The small side walls (Pf) are located in the lower area of the formwork, these panels allowing the overlap with the starting point previously carried out. They are respective curved metal panels made up of the same type of framework as the rest of the panels. Each has in the area lower a spreading longitudinal profile stiffener for correctly transmitting the loads to the shear keys.

[0018] Each of the panels is made up of:

- A rib (1) having an isosceles trapezoidal section provided with lugs in the vertexes, the two outer lugs (12), a prolongation of the larger base, they are joined together by means of a bolt or a similar means which allows the rotation of the two consecutive ribs.
with respect to one another. In addition, the inner lugs (11) of two annexed ribs are joined by means of a telescopic prop (4) which is immobilised during the assembly at the appropriate distance for internally defining a polygonal ring of with a radius and configuration in accordance with the tunnel to be constructed (A-B-C see Figure 1).

- A secondary rib (2) which is joined to the main rib (1) by any conventional means and which externally has an arched surface (21) in accordance with the specific configuration of that area of the tunnel to be constructed. It can be a part with a changeable structure, formed by means of articulated and movable plates or a fixed and non-movable structure.

- A steel sheet (31) about 6 mm thick as formworking skin supported on longitudinal resistant profiles (32) which transmitting the loads which they receive from the reinforced sheet metal to the ribs. These flexible steel sheets (3) make up the skin of the formwork in a surface having the length of the formwork and the width corresponding to a sector of tunnel, defined by one of the intermediate parts (2) supporting it and by the rib or ribs (1) forming one of the inner structural rings.

[0019] A rib stiffening prop (4) is placed between two consecutive panels, which prop is a metal part with a cylindrical body having threaded screws in opposite directions at each side of the central body. This part serves for stiffening the attachment between the formwork panels during the concreting and/or assembly phase. By rotating the body of the stays the length thereof is varied for adapting it to the required measurement.

[0020] Figure 12 shows the structure of a panel in which the auxiliary rib (2) is an element with the curvature in accordance with the sector of each particular tunnel. In this case these parts are constructed with the specific curvature of each construction job, being the only element of the system which does not have a universal use and which is not usually reusable in successive construction jobs. The assembly of this type of panel is seen in Figures 3 to 6: starting from a sheet metal module (31), fixed on longitudinal profiles (32), the secondary rib (2) is brought closer and is fixed to it by means of screws, based on the fact that in this case, said secondary rib (2) already has the radius of curvature suitable for the section of tunnel to be constructed; finally the secondary rib (2) and the primary rib (1) are screwed together for forming a single body which will determine a particular sector of the tunnel.

[0021] Figure 13 shows the structure of a panel having in this case an a variable outer curvature, capable of adapting to the specific curvature of each sector of the tunnel, whereby they are also universal elements which can be adapted to any radius of curvature. In this case the intermediate rib (2) is formed by means of articulated movable plates (21), joined by means of screws (23) to the main rib (1) and articulated to one another through arched lugs (22) which allow, together with the aforementioned, modifying the outer curvature of the part (2) for adapting it to the specific curvature of each sector of the tunnel.

[0022] Figures 14 to 16 illustrate the assembly sequence of each of these panels. The rib (1) is the same in each case, as is the formworking skin (3), what changes here with respect to Figures 3-6 is the structure of the rib (2), which is an element having a configuration and curvature adaptable to each case. To that end, there is a line of plates (21) which are articulated to one another through the arched windows (22) which allow forming a general line with the desired curvature; it is immobilised in the position predefined by means of the screws (23) joining the different parts (21) with the main rib (11), defining the radius of curvature of each plate (21) in the set of the part (2). The assembly sequence means first relating the screws (23) to the rib (1) and subsequently, once the desired curvature is established, fixing said screws and the lugs (22) in the established position.

[0023] The formwork carriage (c) is made up of two equal gantries (c1) located in the transverse position joined by means of longitudinal beams, braced to one another by means of crosspieces. This carriage is designed for not receiving loads during the tunnel concreting process, i.e., it must solely and exclusively be used for moving the formwork from one course to the next and serve as a base for positioning the formwork in the correct place before concreting. To move it, the carriage slides on wheels (c2) on railway tracks which have to be perfectly placed before starting the movement.

[0024] The carriage is structurally formed by two caisson-shaped, reinforced sheet metal gantries (c1) having a maximum height clearance suitable for concreting the tunnel. The gantries are longitudinally braced by means of two parallel beams the section of which has the shape of a reinforced caisson. The metal formwork rests on the longitudinal beams through four anchoring points on which the relative position of the formwork with respect to the axis of the carriage can be varied with the aid of hydraulic shifting cylinders for correcting small deviations in the alignment of the formwork or for laying out when passing through a curve.

[0025] The legs of the moving carriage are height adjustable by means of hydraulic cylinders arranged inside the female part. This height adjustment allows performing the formwork and stripping operation with respect to the keystone of the tunnel. For achieving the forward movement of the set, the four hydraulic motors in the drive wheels, one in each leg of the transport carriage, are simultaneously activated. Once the formwork is positioned to the level and the lower portions adjusted to the footing and the mechanical rib stiffening props, the pressure is released from the hydraulic cylinders of the carriage for preventing them from bearing a load during the concreting phase.

[0026] Concreting gates and inspection windows spread out uniformly along the entire formwork surface.
are arranged in these panels, the purpose of which is to facilitate both the pumping of concrete towards the inside of the tunnel and the inspection of the concreting process by the construction personnel. At the same time a series of supports are arranged for the surface vibrators which will facilitate the concrete mass vibrating operation. The formwork is provided with gates in the keystone panels which allow coupling pipes for the pumping of concrete towards the inside of the formwork in the final phase, when the upper part of the vault is concreted. As an additional safety measure, the formwork has filling reference points for being able to stop the final pumping of concrete on time and thus prevent transmitting concreting overpressure to the keystone formwork.

[0027] For performing the formwork/stripping operations, first the cylinders (7) are operated, which collapse the small side walls (Pf) towards the inside, next the side walls (Ph) of the tunnel are retracted, operating the corresponding hydraulic cylinders (c3) which allow collapsing the panels with respect to the articulations are. The keystone is formworked/stripped by operating the hydraulic cylinders of the legs.

Claims

1. A formwork for concreting the inner lining of tunnels, made up of a series of panels (P) forming the vault, the sides and the corners of the base of the tunnel, assembled on a carriage (c) which moves the formwork along the longitudinal axis of the tunnel (t), from one course to the next, supported on railway tracks placed previously on the footings/inverts of the tunnel (t1), said formwork panels being provided with articulated connections which allow collapsing the panels forming the small side walls and the sides of the tunnel for stripping and being able to move the formwork to the next placement, before placing it and the subsequent concreting of the corresponding course, characterised in that, from the inside out, it comprises:

a) a resistant structure formed by at least two polygonal rings, perpendicular to the axis of the tunnel, made up of a variable number of ribs (1) which are articulated to one another by the outer side edges (12), which are located closer to the wall of the tunnel, while the two inner edges (11) of two annexed ribs (1) are related to one another by a telescopic prop (4) which allows varying the angle formed by the two consecutive ribs between which it is located, and consequently varying the curvature of the perimeter ring in each sector of the tunnel, such that by also varying the number of ribs (1) it is possible to form a polygonal ring, inside the formwork, adaptable to any measurement and configuration of the tunnel (t) to be constructed;

b) a series of intermediate parts, or secondary ribs (2) externally defining a curvature (21) in accordance with each area or sector of tunnel in which it is assembled, supported on the rib or ribs (1) of the polygonal rings which structure the formwork and makes up the supporting means for the sheet metal defining the skin of the formwork;

c) a series of flexible steel sheets (3), each of which is assembled or formed with the radius of curvature suitable for the area or sector of tunnel to be constructed, making up the skin of the formwork on a surface having the length of the formwork and the width corresponding to a sector of tunnel, defined by one of the intermediate parts (2) supporting it and by the rib or ribs (1) forming the inner structural rings.

2. The formwork according to claim 1, characterised in that in order to assemble the set of panels (P) forming the formwork on the carriage and at a structural level in each particular tunnel, said panels (P) are grouped and structured in the following sections:

a) an upper section defining the vault of the tunnel, made up of a variable number of keystone panels (Pc), which are symmetrically assembled at both sides of the axis of the tunnel, forming the upper part of the formwork, which, once assembled in the right position and with the appropriate angle, are all braced with at least one prop (5) relating the two end ribs (1) through the inside of the formwork, while at the same time allowing elevating and placing it on the formwork driving carriage (c);

b) respective side sections made up of a variable number of side wall panels (Ph) which, once joined to one another, are assembled in the respective sides of the vault section through an articulation located on the inner face, operated by means of a cylinder (c3) or similar means, allowing the collapsing of the lower end towards the inside of the tunnel in order to facilitate the transport and stripping operations, being stiffened with props during concreting; and

c) respective panels located under the side sections making up the small side walls (Pf) or side closures of the tunnel with the lower footings, which articulate by collapsing towards the inside of the tunnel for facilitating the transport and stripping operations, being operated by a cylinder or similar means (7).

3. The formwork according to claim 1, characterised in that the intermediate parts or secondary ribs (2) are elements with a changeable structure, formed by means of articulated and movable plates (21) which allow modifying the outer curvature of each
part for adapting it to the specific curvature of each sector of the tunnel.

4. The formwork according to claim 1, **characterised in that** the intermediate parts or secondary ribs (2) are elements constructed with the specific curvature in accordance with each sector of each particular tunnel.
Fig. 14

Fig. 15

Fig. 16