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(54) **PREFABRICATED BRIDGE GIRDER**

(57) A prefabricated bridge girder comprises a span zone (100) separated by transition zones (101) from support zones (102). The span zone (100) comprises a horizontal support section in the form of a steel T-bar (1) whose web (2) with a horizontal upper edge is directed upwards. To the upper edge of the web (2) of the steel T-bar (1) a longitudinal reinforced concrete upper flange (3) is fixed. In the transition zone (101), the web (2) of the steel T-bar (1) is gradually shorter forming a diagonal upper edge (9) and at the end of the transition zone (101) the web (2) is by 50% shorter than the web (2) of the steel T-bar (1) in the span zone (100), and comprises the horizontal upper edge. In the transition zone (101), the reinforced concrete upper flange (3) takes the form of a

reinforced concrete T-bar whose web (7) directed downwards comprises a diagonal bottom edge (8), parallel to the diagonal upper edge (9) of the web (2) of the steel T-bar (1). The reinforced concrete flange (3) in the span zone (100) and the reinforced concrete T-bar (6) in the transition zone (101) comprise members connecting it with connecting members at the upper edges of the web (2) of the steel T-bar (1). At the end of the transition zone (101), from the side of the support zone (102), the web (2) of the steel T-bar (1) is constant in height, shorter by 50% than the web (2) in the span zone (100). The end of the transition zone (101) comprises at least one horizontal reinforcing bar (16) on each side of the web (2) which passes through the closed vertical stirrup (13).

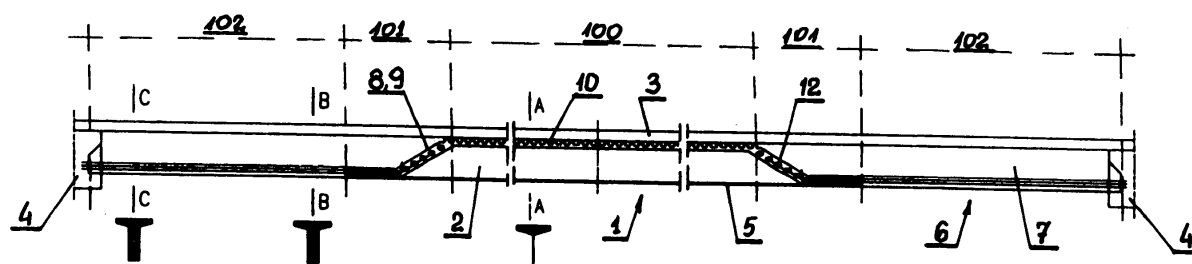


Fig. 1

Description

[0001] The invention relates to a prefabricated bridge girder in the form of a horizontal or diagonal steel beam comprising, in particular, a bridge span and transferring loads to main supports in the form of walls or columns.

[0002] In prior art solutions, bridge girders are typically made in the form of bearing trusses or beams, for example in the form of I-beams on which a reinforced concrete slab is arranged intended to be used by vehicles or intended for rail systems to be laid for railroad vehicles. Girders made of one material are known, for example steel or reinforced concrete but also made of various materials, including partially of steel and partially of reinforced concrete.

[0003] From patent specification US 2011/0120051 a supporting system is known comprised of at least two joists and at least one bridging member. The joists, as an example, have the form of I-beams the flanges of which are connected by parallel bridge flat bars, in planes parallel to the planes of the webs of the I-beams. The flat bars contain coupling holes.

[0004] A number of other known solutions provide for girders made in the form of steel reinforced concrete beams. Such a known solution of a precast steel concrete panel is disclosed in patent specification US 9,464,437. According to this known solution, a support panel has the form of a beam comprising a steel I-beam fitted on both sides of a web with platforms made of reinforcing members attached to the web of the I-beam. The triangular platforms comprise a top platform substantially parallel to the plane of the top flange of the I-beam and a bottom support platform connected with it resting on the bottom flange of the I-beam. The joints of the platforms on both sides of the web of the I-beam are connected by longitudinal reinforcing members, parallel to the I-beam. The whole is filled with concrete, forming a panel with a top working plane. A number of panels can be connected by side longitudinal edges into a single working plane.

[0005] Another known solution of a steel concrete girder is disclosed in patent specification US 2010/0287878. This solution provides for a structure of a steel concrete composite beam comprising a cold-formed steel section and reinforced concrete. The basis of the beam comprises a steel inward lipped section filled with concrete. On the beams with the structure presented, a reinforced concrete overlay slab is attached. The beam comprises non-combustible components, both in coat layers and in the composition of concrete material.

[0006] In another solution known from patent specification US 5,852,905, a further solution of a composite girder is disclosed. According to this solution, the base of the girder is a steel section in the form of an I-beam. To the I-beam flanges longitudinal flat bars are fixed in planes parallel to the plane of the I-beam web. At the prefabrication factory the composite girder with a bottom stiffening slab and an upper concrete slab can be prepared. Such a combination of steel-concrete compo-

nents makes it possible to increase the stiffness of the girder using the tensile strength of steel components and the compressive strength of reinforced concrete components. Between the girders arranged in parallel, at a construction site reinforced concrete slabs can be arranged and the whole can be filled with a layer of concrete overlay with a usable surface.

[0007] The problem to be solved in composite beams is a combination of steel components, such as an I-beam or a T-bar with reinforced concrete components. The problem of combining these two materials is due to the fact that a girder, for example a bridge girder, operates at varying loads, and the operating parameters of steel and reinforced concrete under these conditions are different. These different parameters are the result of substantially different properties of these two materials, as described above. At the same time, designers take effort to eliminate as many welded joints as possible, especially those which need to be made at a construction site. To combine these two materials, the properties of which are complementary in the structure of a composite girder, in some known solutions holes in steel through which concrete material penetrates are proposed. In other known solutions, elements protruding from steel parts of a girder which penetrate into concrete material are proposed.

[0008] Such a known solution is disclosed in patent specification US 2,987,855. In this known solution the base of a composite beam is a section in the form of an I-beam. To the upper flange of the I-beam sets of studs perpendicular to the surface of the flange of the I-beam are fixed. At their free ends the studs comprise support flanges which prevent the studs from protruding from concrete material once a layer of reinforced concrete is poured and hardened on the upper flange of the I-beam.

[0009] Another known solution to this problem is disclosed in patent specification US 5,664,378. In this solution on the longitudinal support flanges of T-bars transverse T-bars are arranged and fixed webs upward. The webs of the transverse T-bars comprise at certain intervals slits for transverse bars cooperating with a bottom layer of concrete. However, the upper edges of the transverse T-bars comprise protrusions arranged in a comb-like manner and recesses separating them, which add to the mechanical connection of the upper layer of concrete, for example a layer of concrete overlay, with the transverse steel T-bars, and thus with support T-bars.

[0010] Another known solution of the structure of a composite girder, also referred to as a steel-concrete composite girder, is disclosed in the patent specification of Polish patent application No. P.386219. According to this known solution, the web of an I-steel section was cut into two T-sections. In one embodiment of the girder, according to this known solution, two T-bars are arranged next to each other and the resulting inside with a U section is filled with reinforced concrete. The reinforcement of an upper reinforced concrete slab is based on the upper comb-shaped edges of the webs. In another embodiment of the girder, according to this known solution, the base

of the girder is only one T-section usually obtained by a longitudinal cut of an I-section, with the formation of an upper comb edge of the web of the T-bar using plasma cutting or water jet cutting.

[0011] The term comb edge is understood in this patent specification as the longitudinal edge of the web of the T-bar containing a plurality of projections formed thereon and semi-closed recesses separating the projections from one another. The projections and recesses on the edge of the web are aimed at increasing the strength of the connection of the T-steel section with a layer of reinforced concrete. In this known solution a number of design solutions for forming the comb edge of the web of the T-bar are provided. From one I-section, once a web is longitudinally cut, two T-sections are obtained, which can be arranged, according to the invention, next to each other to obtain one girder, or in another solution according to this invention, based on any single T-section one girder can be made. In each of these cases in this known solution the girder along the entire length comprises a steel reinforced concrete beam. Specific shapes for cutting an I-section are proposed here, where cutting along a line determining the centre of the height of the web is along a line determining another projections and semi-closed recesses separating them. The line dividing an I-beam into two T-bars determines another identical projections in the shape similar to the letter T and another semi-closed recesses separating them. In the semi-closed recesses reinforcing bars can be arranged without them being cut and welded, and then the steel section prepared as above can be poured with concrete.

[0012] Further development of the cutting line of an I-beam into two T-bars is disclosed in Polish patent specification PL 219664. Cutting an I-beam into two T-bars is also proposed here, where along the cutting line consecutive projections are formed in the shape similar to the letter T and semi-closed recesses separating them for reinforcing bars and concrete as the second material used in the structure of a composite girder. According to this solution, the cutting line is directed by a continuous and uninterrupted cut starting with a straight section and farther along curvilinear sections leaving residual material, namely offcuts. This makes it possible to stop the cutting process, as required, between offcuts, or beyond the construction material resulting in that no dangerous structural notch is left on the construction material.

[0013] In another specification of Polish patent application No. P.401662, another solution of a composite girder for the construction of bridges or viaducts is disclosed. According to this known solution, a girder is a combination of a steel girder in the form of a T-bar with a comb-shaped edge of a web and a reinforced concrete flange or slab. In a substantial load-bearing part, the girder comprises at least one T-bar with its web facing upwards. In another solution, according to this patent specification, the steel girder comprises two parallel T-bars with their webs facing upwards so that between the webs of the T-bars a section is formed comprising an inner

channel with a U-shaped section, filled with reinforced concrete. In the transition area of the substantial span zone into the girder's support zone, the height of the webs of the section is gradually decreased along its length towards the span supports, and the thickness of the upper reinforced concrete beam is increased towards the bottom edge of the steel section. Within the girder's support zone, a composite section is gradually changed into a reinforced concrete section. Therefore, according to this known solution, the composite girder in the span zone has the form of a steel section in the form of at least one T-bar with a bottom flange and with an upper longitudinal reinforced concrete slab, in the transition zone is gradually changed into a reinforced concrete beam. In the transition zone, as shown in this known solution, the steel girder gradually disappears towards the T-bar flange, and it is gradually replaced by a reinforced concrete beam. In the support zone, it comprises only a reinforced concrete beam.

[0014] The problem in this kind of structures is a transition zone, where a diagonal upper edge of a disappearing steel T-bar is connected with a reinforced concrete beam gradually replacing it. According to this known solution, near the diagonal edge of the steel girder there are holes through which reinforcing bars of a reinforced concrete beam pass.

[0015] A combination of a steel girder with a layer of reinforced concrete thereon has made it possible to obtain good tensile strength of a bottom steel beam which deflects between supports, with good compressive strength of an upper layer of reinforced concrete, which prevents excessive deflection of the steel beam. The purpose of the invention is to solve the problem of increased fatigue resistance of a connection of a steel beam with a concrete beam in a transition zone of a girder to avoid fatigue cracks in reinforced concrete.

[0016] The prefabricated bridge girder, according to the invention, has been disclosed in claim 1 and the subsequent claims.

[0017] The girder comprises a span zone separated by at least one transition zone from at least one support zone. The end of the girder's support zone is designed to rest the girder on a support.

[0018] The span zone comprises a horizontal support section in the form of at least one steel T-bar whose web with a horizontal upper edge is directed upwards, and a flange of the steel T-bar comprises a base of the girder in the span zone. To the upper edge of the web of the steel T-bar a longitudinal reinforced concrete flange combined with the T-bar is fixed.

[0019] The girder's span zone from at least one side ends with the support zone which, once the girder is brought into its operating position, rests on the bridge support foundation. Between the span zone and each support zone of the girder there is the transition zone which separates the span zone from the support zone.

[0020] In the transition zone, the web of the above-mentioned steel T-bar is gradually shorter forming a di-

agonal edge in the transition zone. At the end of the steel T-bar, at the end of the transition zone, the web of the T-bar is at least by 50% shorter than the same web in the girder's span zone. At the end of the transition zone, the web of the steel T-bar comprises the horizontal upper edge. In the same transition zone, the reinforced concrete upper flange takes the form of a T-bar with a reinforced concrete web. The reinforced concrete web comprises a diagonal bottom edge, tangent to the diagonal upper edge of the web of the steel girder in this zone.

[0021] Both horizontal edges of the web of the steel T-bar, namely the horizontal upper edge in the span zone and the horizontal upper edge at the end of the transition zone comprise members connecting these edges with the reinforced concrete flange, in the form of comb arranged protrusions and recesses separating them.

[0022] The prefabricated girder is characterised, according to the invention, in that near the diagonal upper edge of the web of the steel T-bar, in the transition zone, the connecting members have the form of holes. At least one reinforcement member in the form of a horizontal U-shaped stirrup and at least one reinforcement member in the form of a closed vertical stirrup passes through each hole. The stirrups are situated in the reinforced concrete T-bar with their arms being oriented perpendicularly and/or in parallel to the surface of the upper flange of the reinforced concrete T-bar.

[0023] At the end of the transition zone, from the side of the support zone, the steel T-bar is constant in height, shorter by 50% than the steel T-bar in the span zone. At the end of the transition zone, the members connecting the web of the steel T-bar and the web of the reinforced concrete T-bar have the form of holes. At least one reinforcement member in the form of the closed vertical stirrup passes through each hole. The end of the transition zone comprises at least one horizontal reinforcing bar on each side of the web of the steel T-bar and the bar passes through the corners of this closed vertical stirrup. Said reinforcing bars are routed between the arms of the stirrups and the web of the T-bar, in parallel to the upper edge of the web of the T-bar.

[0024] At the end of the transition zone, the width of the bottom flange of the steel T-bar is reduced on both sides. This means that in the transition zone, within the diagonal edge of the web of the steel T-bar, its flange is constant in width, the same as the width of this flange in the span zone. At the end of the transition zone, within the horizontal lower edge of the web of the T-bar, the width of the flange is gradually decreased. With such a solution, according to the invention, a more flexible zone of the end section of the steel T-bar has been introduced, making it possible to avoid stresses hitherto accumulated in known solutions at the end edge of the steel T-bar. In prior-art solutions, stresses accumulated in one place resulted in scratches on reinforced concrete after a certain period of operation of the girder.

[0025] In the area of the diagonal edge of the web of the T-bar, holes have been proposed as members con-

necting the web of the T-bar with reinforced concrete. The proposed holes are preferably oval, elongated in a horizontal direction.

[0026] More than one stirrup can pass through one said hole. The arms of each stirrup can be arranged in a direction perpendicular or parallel to the surface of the reinforced concrete upper flange. In one hole stirrups can be mounted whose arms are arranged in mutually perpendicular directions.

[0027] In another embodiment of the girder, according to the invention, the girder's support zone, at the free end can comprise an additional transition zone with an additional steel T-bar. This means that the last part of the girder's reinforced concrete support zone comprises another transition zone by means of which the girder rests on the support. The term support in this patent specification should be understood as a foundation on which the end of the girder is arranged. This further transition zone also comprises a reinforced concrete composite structure, where the web of the additional steel T-bar is constant in height and shorter by at least 50% than the web of the steel T-bar in the span zone. The web of the additional T-bar in the additional transition zone comprises connecting members and is completely covered with concrete over its entire length. In a preferred embodiment, the connecting members can have the form of comb arranged protrusions and semi-closed recesses separating them on the upper edge of the web of the additional steel T-bar.

[0028] The bridge girder, according to the invention, can also contain an additional reinforcing bar arranged outside the vertical stirrups, in parallel to the upper edge of the web in the span zone, further in parallel to the diagonal upper edge of the web of the steel T-bar in the transition zone and further in parallel to the upper edge of the web at the end of the girder's transition zone. This additional reinforcing bar is mounted in ancillary stirrups having their arms directed perpendicularly to the surface of the reinforced concrete upper flange of the girder.

[0029] The width of the web of the reinforced concrete T-bar in the transition zone and in the reinforced concrete support zone is preferably the same as the width of the flange of the steel T-bar in the span zone and in the substantial part of the transition zone.

[0030] Within transition from the transition zone to the support zone, to the web of the steel T-bar at least one reinforcing bar is attached, parallel to the bottom of the girder and anchored in the reinforced concrete support zone.

[0031] The prefabricated bridge girder, according to the invention, is a hybrid solution, namely it is a structure combined with steel members connected with reinforced concrete members. In this type of known solutions, the upper edge of the web of the T-bar was equipped with comb arranged protrusions and semi-closed recesses separating them. However, with an increase in fatigue damage, parts of reinforcement from said semi-closed recesses could protrude, in particular on the diagonal

edge of the web of the T-bar in the transition zone. This was especially the case for longitudinal reinforcement elements whose hooked ends were arranged in the semi-closed recesses.

[0032] The comb arranged semi-closed recesses on the diagonal edge of the web of the T-bar in the girder's transition zone have been replaced with horizontally elongated holes. In the holes bottoms of stirrups have been arranged whose arms are directed perpendicularly or in parallel to the surface of the reinforced concrete flange. The replacement of the bent ends of reinforcing bars with stirrups and passing horizontal bars through the eyes of the stirrups on both sides of the diagonal plate of the web of the T-bar has additionally stiffened the girder's transition zone and the support zone. This is important especially in the girder's transition zone where the web of the T-bar becomes shorter, farther the width of the flange of the T-bar is reduced, and the whole T-bar disappears in the support zone where only said longitudinal reinforcing bars remain in a layer of concrete. The width and, consequently, the section of the steel flange of the T-bar in this zone are reduced, so that each of the connecting holes transmits the same force on a reinforced concrete section. It has been found that this prevents scratches on a reinforced concrete member.

[0033] The additional stiffening of the transition zone results from the fact that the holes with the stirrups are designed in the area of the diagonal edge of the T-bar at different heights, and thus horizontal reinforcing bars are arranged at different heights between the stirrups and the web, on both sides of the web.

[0034] Supplementing this solution by designing the additional composite transition zone in the form of the steel T-bar and the reinforced concrete beam at the end of the support zone has made it possible to increase the strength of the end part of the support zone. As a result, this has made it possible to increase the span of the girder, according to the invention.

[0035] The prefabricated bridge girder is shown in the embodiments in the accompanying drawings in which the individual figures show:

- Fig. 1 - the straight girder.
- Fig. 2 - the girder, according to Fig. 1, with the extreme transition zones.
- Fig. 3 - the girder with the arched support zones.
- Fig. 4 - the girder, according to Fig. 3, with the extreme transition zones.
- Fig. 5 - a top view of the girder's reinforcement in the transition zone.
- Fig. 6 - a bottom view of the girder's reinforcement, according to Fig. 5.
- Fig. 7 - a part of the reinforcement at the point of contact of the horizontal edge and the diagonal edge of the steel T-bar.
- Fig. 8 - a bottom view of a part of the reinforcement within the bottom part of the diagonal edge of the steel T-bar.

Fig. 9 - a top view of a part of the reinforcement, according to Fig. 8.

Fig. 10 - a top view of a part of the reinforcement of the point of contact of the span zone and the transition zone.

Fig. 11 - a top view of a part of the reinforcement of the point of contact of the transition zone and the support zone.

[0036] Fig. 1, Fig. 2, Fig. 3 and Fig. 4 show the girder, according to the invention, in four embodiments. The girder is a hybrid solution, which means that in part it is a composite reinforced concrete steel beam, and in part a reinforced concrete beam. The girder comprises a prefabricated unit and is transported as a finished component for the installation of a bridge structure at a construction site. The prefabricated bridge girders, according to the invention, shown in the embodiments in the accompanying drawings are about 25 meters long and weigh about 28 tonnes.

[0037] In all the embodiments shown, the girder comprises one span zone 100, two transition zones 101 and two support zones 102. It is not excluded in other embodiments, according to the invention, that the girder can be asymmetric, namely it can comprise, for example, except for the span zone 100, only one transition zone 101 and only one support zone 102. The term support zone 102 is understood in this patent specification as the girder's zone the end of which rests on a foundation on which the bridge spans are arranged. The examples of the girders shown in the figures rest on supports on both sides.

[0038] Figs. 1-4 also show schematically an arrangement of the main horizontal reinforcing bars and schematically an arrangement of the main connecting members in the form of the semi-closed recesses and the holes connecting the edge of the steel T-bar 1 with the girder's reinforced concrete members. Fig. 1 and Fig. 2 show in detail subsequent zones of both embodiments of the girder. In Fig. 3 and Fig. 4, the zones are marked more schematically than in Fig. 1 and Fig. 2, for the clarity of the figures.

[0039] Fig. 1 shows the girder in the first embodiment. In this figure, the span zone 100, two transition zones 101 and two extreme support zones 102 are shown schematically. The span zone 100 comprises a horizontal support section in the form of a steel T-bar 1 whose web 2 with substantially horizontal upper edge is directed upwards, and a flange 5 of the steel T-bar 1 comprises the girder's base in the span zone 100. In these embodiments, the web 2 is 1000 mm high, and the bottom flange 5 is 300 mm wide. The T-bar is made of S460 grade steel. To the upper edge of the web 2 of the steel T-bar 1 a longitudinal reinforced concrete upper flange 3 with a width of 1200 mm, made of C 40/50 concrete, combined with the edge of the web 2 is fixed. When at least two prefabricated bridge girders, according to the invention, are put together at a construction site, between both reinforced concrete flanges 3 known bridge decks not

shown in the figures are arranged on which a prior art layer of concrete overlay constituting the bridge surface is poured.

[0040] As shown in the accompanying drawings, the girder's span zone 100 from both sides ends with the reinforced concrete support zone 102 which, once the girder is brought into its operating position, rests on the bridge support 4. Between the span zone 100 and each support zone 102 of the girder there is the transition zone 101 which separates the span zone 100 from the support zone 102.

[0041] In the transition zone 101, the web 2 of the above-mentioned steel T-bar 1 is gradually shorter forming a diagonal edge in the transition zone 101. At the end of the transition zone 101 of the steel T-bar 1, the web 2 is at least by 50% shorter than the same web 2 in the girder's span zone 100 and has a horizontal upper edge. In the same transition zone 101, the reinforced concrete flange 3 takes the form of a reinforced concrete T-bar 6 whose downwardly extending web 7 comprises a diagonal bottom edge 8. This bottom edge 8 of the web 7 of the reinforced concrete T-bar 6 in the transition zone 101 is parallel to a diagonal upper edge 9 of the web 2 of the steel T-bar 1.

[0042] Fig. 1 shows examples of the girder's cross-sections in individual zones. In the span zone 100, the A-A cross-section is shown. As can be seen, the girder comprises in this zone a structure combined with the steel T-bar comprising the web 2 directed upwards and the bottom flange 5. In the support zone 102, the B-B and C-C cross-sections are shown, where this part of the girder, according to the invention, comprises the reinforced concrete T-bar 6 whose web 7 has the width corresponding to the width of the web 5 of the steel T-bar 1, as shown in the subsequent figures.

[0043] Fig. 5 shows a top view of the girder's reinforcement in the transition zone 101 with portions of the adjacent span zone 100 and the support zone 102 adjacent from the other side. The reinforced concrete upper flange's 3 reinforcement is shown in a top view. Holes 12 arranged along the diagonal edge of the web 2 of the steel T-bar 1 are shown here. In these embodiments, the holes 12 are 100 mm high and 150 mm long, with a longer dimension being a horizontal dimension. This figure shows that each hole 12 in this embodiment comprises one vertical stirrup 13 made of a $\varnothing 16$ mm bar and one horizontal stirrup made of a $\varnothing 12$ mm bar. The same part is shown in a bottom view in Fig. 6. This figure shows the bottom flange 5 of the steel T-bar 1. At the end of the transition zone 101 described above and shown in the previous figures, the width of the bottom flange 5 of the steel T-bar 1 in this embodiment is gradually decreased. An additional reinforcing bar 17 is also shown here.

[0044] The vertical stirrups 13 are closed in these embodiments. This means that at the stage of preparation of reinforcement for these members, U-shaped stirrups are arranged in the holes 12, and then upper arms of each stirrup are joined by welding.

[0045] In the second embodiment, shown in Fig. 2, the girder comprising additional composite zones 103 at the ends of the support zones 102 is shown. The A-A and B-B cross-sections are the same as shown in Fig. 1. However, the C-C cross-section shows that in the additional composite zone in the bottom part of the web 7 of the reinforced concrete T-bar 6, an additional T-bar 15 is covered with concrete with a horizontal upper edge of a web, provided with a set of comb arranged protrusions 10 described above, separated by semi-closed recesses 11 designed for the vertical stirrups 13 being arranged therein. The same connecting members are described for the horizontal upper edge of the web 2 of the steel T-bar 1.

[0046] The reinforced concrete upper flange 3 in the span zone 100 and the reinforced concrete T-bar 6 in the transition zone 101 comprise members connecting them with the upper edges of the web 2 of the steel T-bar 1. However, both horizontal upper edges of the web 2 of the steel T-bar 1 comprise connecting members in the form of the comb arranged protrusions 10 and the semi-closed recesses 11 separating them. This is shown in Fig. 7. Near the diagonal edge 9 of the web 2 of the steel T-bar 1, in the transition zone 101, the connecting members have the form of holes 12. At least one reinforcement member in the form of the U-shaped stirrup 13 passes through each hole 12 of the diagonal web 2, with the stirrups' 13 arms being oriented perpendicularly to the surface of the reinforced concrete upper flange 3. Subsequent horizontal stirrups 14 whose arms are arranged horizontally also pass through the holes 12. The term horizontally should be understood here that the arms of the stirrups 14 are arranged in parallel to the bottom surface of the girder. The bottom surface of the transition zone 101 and the support zone 102 of the girder can be arranged horizontally or in an approximately horizontal plane, depending on the ground conditions for placing the bridge supports. Also both zones 101 and 102 can comprise a bottom flat surface, as shown in the embodiments in Fig. 1 and Fig. 2, or an arched surface, as shown in other embodiments in Fig. 3 and Fig. 4.

[0047] On each side of the web 2 of the steel T-bar 1 in the transition zone, at least one reinforcing bar 16 having a diameter of $\varnothing 32$ passes through each stirrup 13. Said reinforcing bars 16 are routed between the arms of the stirrups 13 and the web 2 of the T-bar 1, in parallel to the upper edge of the web 2 of the T-bar 1. This is clearly shown in Fig. 5 and Fig. 6.

[0048] The cross-sectional area of said steel T-bar 1, at the end of the girder's transition zone 101, is decreased towards the end of the T-bar 1. This is shown in Fig. 6 and Fig. 8. This means that in the transition zone 101, within the diagonal edge of the web 2 of the steel T-bar 1, its flange 5 is constant in width, the same as the width of this flange 5 in the span zone 101. Further in the transition zone 101, within the horizontal lower edge of the web 2 of the steel T-bar 1, the width of the flange 5 of the T-bar is gradually decreased. This is clearly shown

in Fig. 6 and Fig. 8. With such a solution, according to the invention, a more flexible zone of the end section of the T-bar 1 has been introduced making it possible to avoid stresses hitherto accumulated at the end edge of the flange 3 of the steel T-bar 1. In prior-art solutions, stresses accumulated in this one place resulted in a number of cases in scratches on reinforced concrete after a certain period of operation of the girder.

[0049] In the area of the diagonal edge of the web 2 of the steel T-bar 1, the holes 12 have been proposed as members connecting the web of the T-bar with reinforced concrete. In these embodiments, the proposed holes 12 are oval, elongated in a horizontal direction.

[0050] In this embodiment, two stirrups 13, 14 with U-shaped arms pass through said holes 12. In this embodiment, the arms of each stirrup 13 are arranged in a perpendicular direction. The stirrups 14 are arranged in parallel to the surface of the reinforced concrete upper flange 3. In individual holes 12, in this embodiment, in one hole 12 two or more stirrups 13, 14 can be mounted whose arms are arranged in mutually perpendicular directions.

[0051] In the embodiments shown in Fig. 2 and Fig. 4, the girder's support zone 102, at the free end can comprise the additional transition zone 103. This means that the last part of the girder's reinforced concrete support zone 102 comprises another composite zone by means of which the girder rests on the support 4. The term supports 4 in this patent specification should be understood as a foundation on which the end of the girder is arranged. This further composite zone 103 also comprises a reinforced concrete structure, where the web of the additional steel T-bar 15 is constant in height and shorter by at least 50% than the web 2 of the steel T-bar 1 in the girder's span zone 100. The web of the additional steel T-bar 15 in the additional composite zone 103 is completely covered with concrete over its entire length. This additional T-bar's 15 web is 300 mm high and flange is 300 mm wide.

[0052] The bridge girder, according to the invention, contains in these embodiments two additional reinforcing bars 17 with a diameter of $\varnothing 32$ mm, arranged outside the vertical stirrups 13. This is shown in Fig. 10 and Fig. 11. This additional reinforcing bar 17 initially extends in parallel to the upper edge of the web 2 in the span zone 100, further in parallel to the diagonal edge of the web 2 in the transition zone 101 and further in parallel to the upper edge of the web 2 at the end of the transition zone 102. Said additional reinforcing bar 17 is mounted in ancillary stirrups 18 made of a reinforcing bar with a diameter of $\varnothing 6$ mm, having their arms directed perpendicularly to the surface of the reinforced concrete upper flange 3.

[0053] Fig. 1 and Fig. 2 show in the B-B and C-C sections that the width of the web 7 of the reinforced concrete T-bar 6 is in these embodiments the same as the width of the flange of the steel T-bar 1 in the girder's span zone 100. The girders according to the embodiments shown in Fig. 3 and Fig. 4 have the same structure.

[0054] Within transition from the transition zone 101 to

the support zone 102, to the web 2 of the steel T-bar 1 at least one coupling reinforcing bar 19 is attached, parallel to the bottom surface of the support zone 102.

5 List of designations in the figures

[0055]

1. Steel T-bar.
2. Web of the T-bar.
3. Reinforced concrete upper flange.
4. Support.
5. Flange of the steel T-bar.
6. Reinforced concrete T-bar.
7. Web of the reinforced concrete T-bar.
8. Diagonal bottom edge of the reinforced concrete T-bar.
9. Diagonal upper edge of the steel T-bar.
10. Comb arranged protrusion.
11. Semi-closed recess.
12. Hole.
13. Vertical stirrup.
14. Horizontal stirrup.
15. Additional steel T-bar.
16. Reinforcing bar.
17. Additional reinforcing bar.
18. Ancillary stirrup.
19. Coupling reinforcing bar.
100. Span zone.
101. Transition zone.
102. Support zone.
103. Additional composite zone.

35 Claims

1. A prefabricated bridge girder comprising a span zone (100) separated by at least one transition zone (101) from at least one support zone (102), where the span zone (100) comprises at least one horizontal support section in the form of a steel T-bar (1) whose web (2) with a horizontal upper edge is directed upwards, and to the upper edge of the web (2) of the steel T-bar (1) a longitudinal reinforced concrete upper flange (3) is fixed, where in the transition zone (101) the web (2) of the steel T-bar (1) is gradually shorter forming a diagonal upper edge (9) and at the end of the transition zone (101) the web (2) is by 50% shorter than the web (2) of the steel T-bar (1) in the span zone (100), and comprises the horizontal upper edge, and in this transition zone (101) the reinforced concrete upper flange (3) takes the form of a reinforced concrete T-bar whose web (7) directed downwards comprises a diagonal bottom edge (8) parallel to the diagonal upper edge (9) of the web (2) of the steel T-bar (1), wherein the reinforced concrete upper flange (3) in the span zone (100) and the reinforced concrete T-bar (6) in the transition zone (101)

- comprise members connecting it with the upper edges of the web (2) of the steel T-bar (1), wherein both horizontal upper edges of the web (2) of the steel T-bar (1) in the span zone (100) and at the end of the transition zone (101) comprise connecting members in the form of comb arranged protrusions (10) and semi-closed recesses (11) separating them, **characterised in that** near the diagonal upper edge (9) of the web (2) of the steel T-bar (1), in the transition zone (101), the connecting members have the form of holes (12) and at least one reinforcement member in the form of a horizontal U-shaped stirrup (14) and at least one reinforcement member in the form of a closed vertical stirrup (13) passes through each hole (12) and at least one reinforcement member in the form of the closed vertical stirrup (13) passes through each hole (12), wherein the end of the transition zone (101) comprises at least one horizontal reinforcing bar (16) on each side of the web (2) which passes through the closed vertical stirrup (13).
2. The bridge girder, according to claim 1, **characterised in that** at the end of the transition zone (101), the width of the bottom flange (5) of the steel T-bar (1) is reduced on both sides.
 3. The bridge girder, according to claim 1, **characterised in that** the holes (12) in the transition zone (101) near the diagonal edge (9) of the web (2) of the steel T-bar (1) are oval, elongated in a horizontal direction.
 4. The bridge girder, according to claim 1 or 2, **characterised in that** more than one vertical stirrup (13) and at least one horizontal stirrup (14) pass through one hole (12).
 5. The bridge girder, according to claim 4, **characterised in that** the arms of each stirrup (13,14) are arranged in a direction perpendicular or in a direction parallel to the surface of the reinforced concrete upper flange (3).
 6. The bridge girder, according to claim 1 or 2, **characterised in that** the horizontal reinforcing bars (16) are arranged between the arms of the stirrups (13) and the web (2) of the steel T-bar (1).
 7. The bridge girder, according to claim 1, **characterised in that** the girder's support zone (102), at the free end comprises an additional composite zone (103) with an additional steel T-bar (15), where the web of the additional steel T-bar (15) is constant in height and shorter by at least 50% than the web (2) of the steel T-bar (1) in the span zone (100), and on the upper edge the web of the additional steel T-bar (15) comprises connecting members.
 8. The bridge girder, according to claim 7, **characterised in that** the connecting members have the form of comb arranged protrusions (10) and semi-closed recesses (11) separating them.
 9. The bridge girder, according to claim 1, **characterised in that** it contains an additional reinforcing bar (17) arranged outside the vertical stirrups (13), in parallel to the upper edge of the web (2) of the steel T-bar (1) in the span zone (100), further in parallel to the diagonal upper edge (9) of the web (2) in the transition zone (101) and further in parallel to the upper edge of the web (2) at the end of the transition zone (101).
 10. The bridge girder, according to claim 9, **characterised in that** the additional reinforcing bar (17) is mounted in ancillary stirrups (18) having their arms directed perpendicularly to the surface of the reinforced concrete upper flange (3).
 11. The bridge girder, according to claim 1, **characterised in that** the width of the web (7) of the reinforced concrete T-bar (6) in the transition zone (101) and in the reinforced concrete support zone (102) is the same as the width of the flange (5) of the steel T-bar (1) in the span zone (100).
 12. The bridge girder, according to claim 1, **characterised in that** within transition from the transition zone (101) to the support zone (102), to the web (2) of the steel T-bar (1) at least one coupling reinforcing bar (19) is attached by welding, parallel to the bottom of the girder and anchored in the reinforced concrete support zone (102).

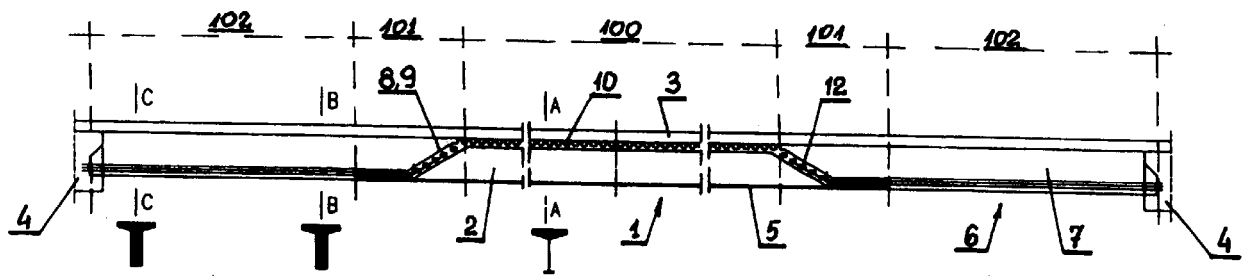


Fig. 1

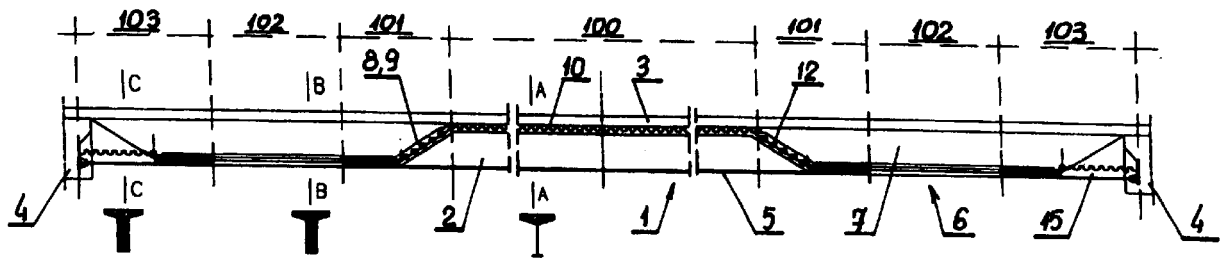


Fig. 2

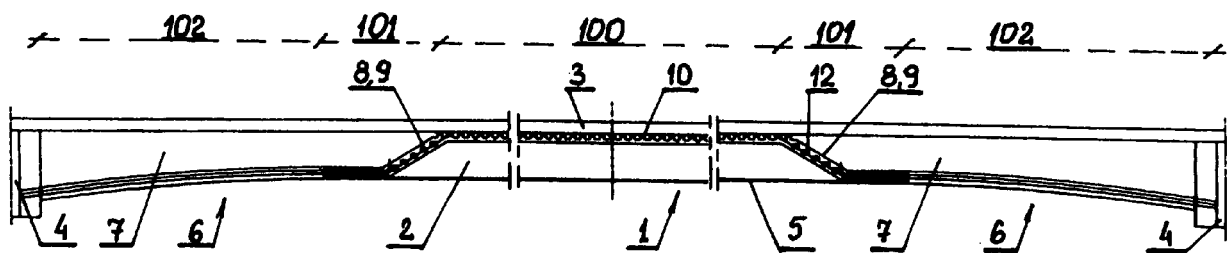


Fig. 3

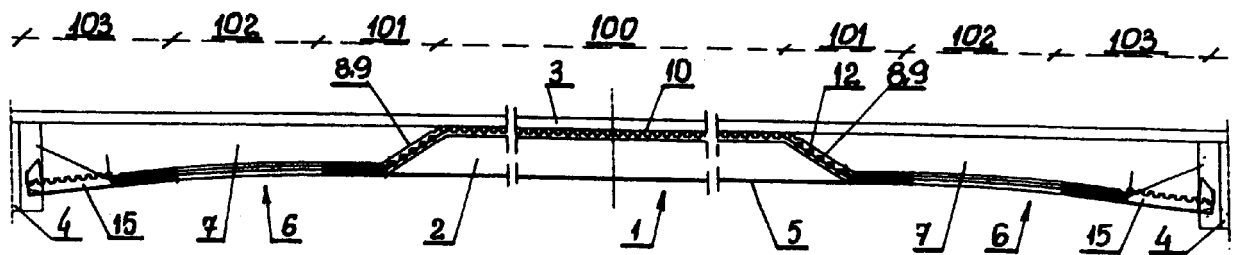
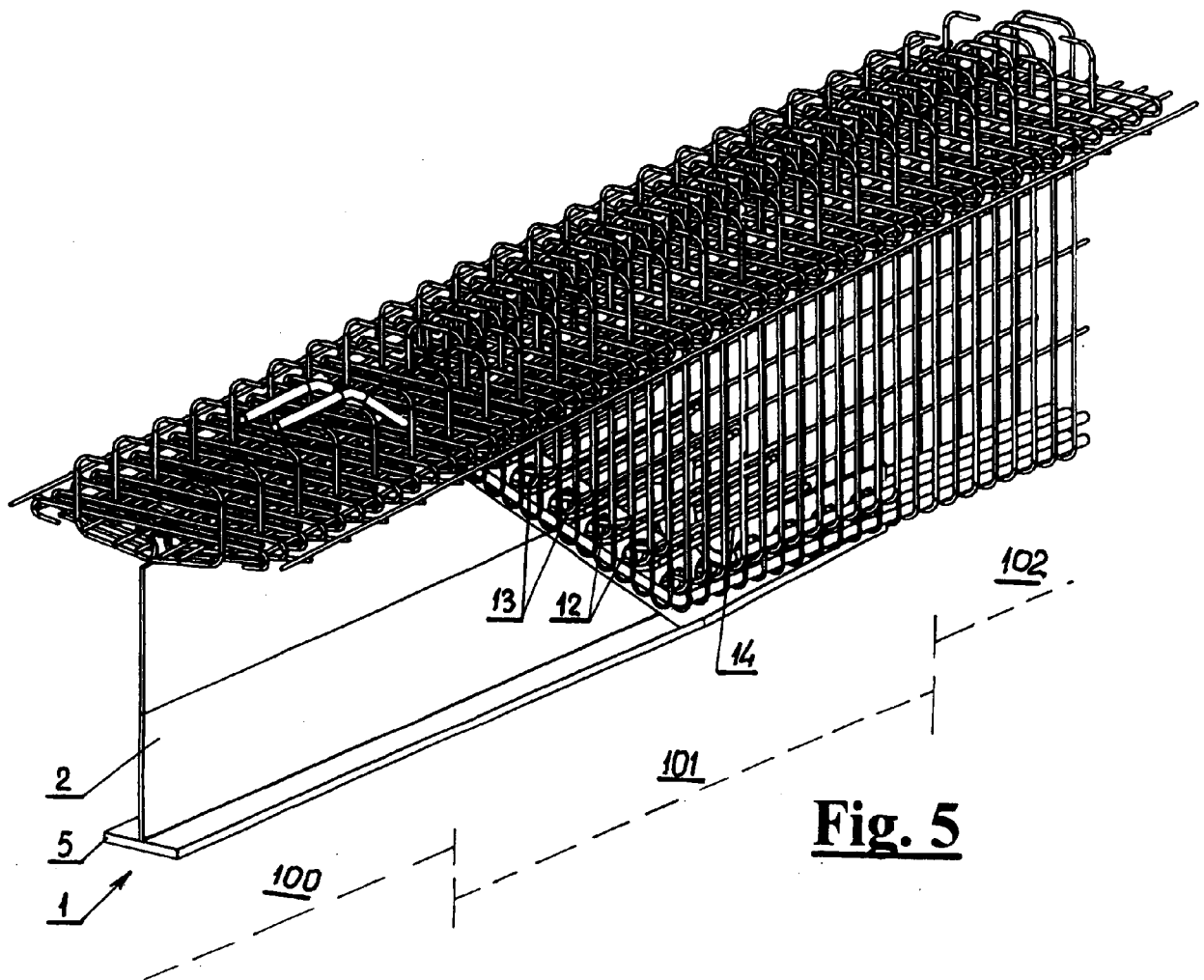


Fig. 4



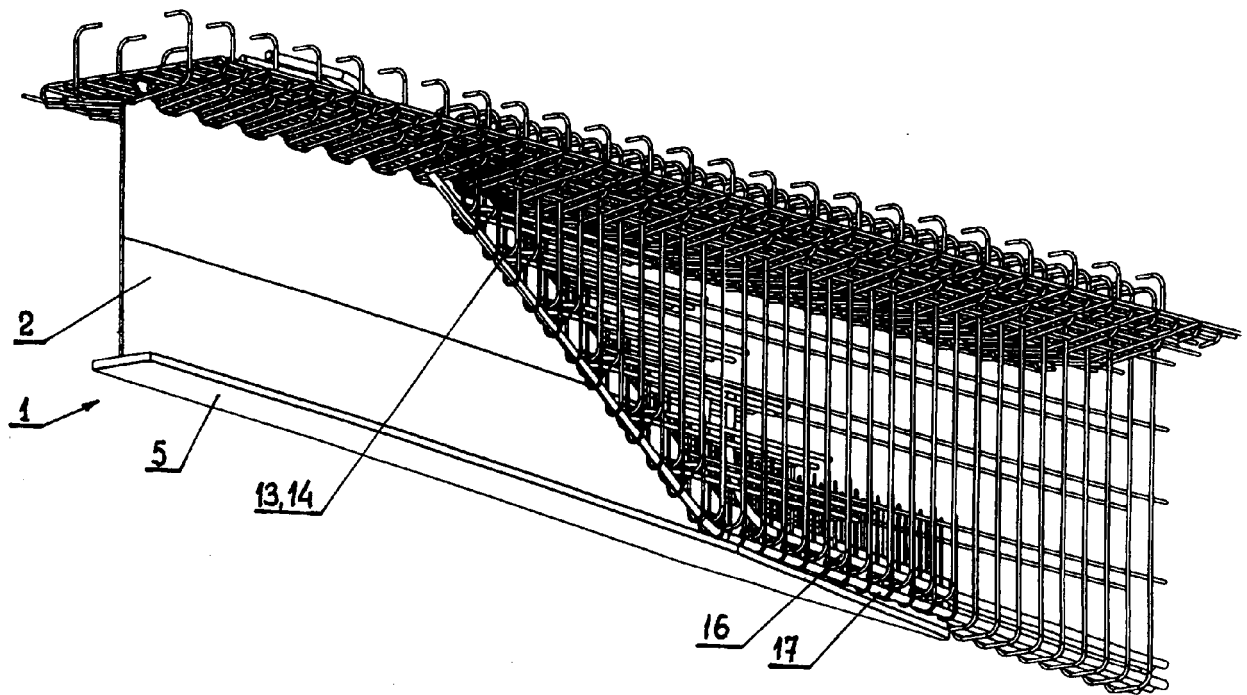


Fig. 6

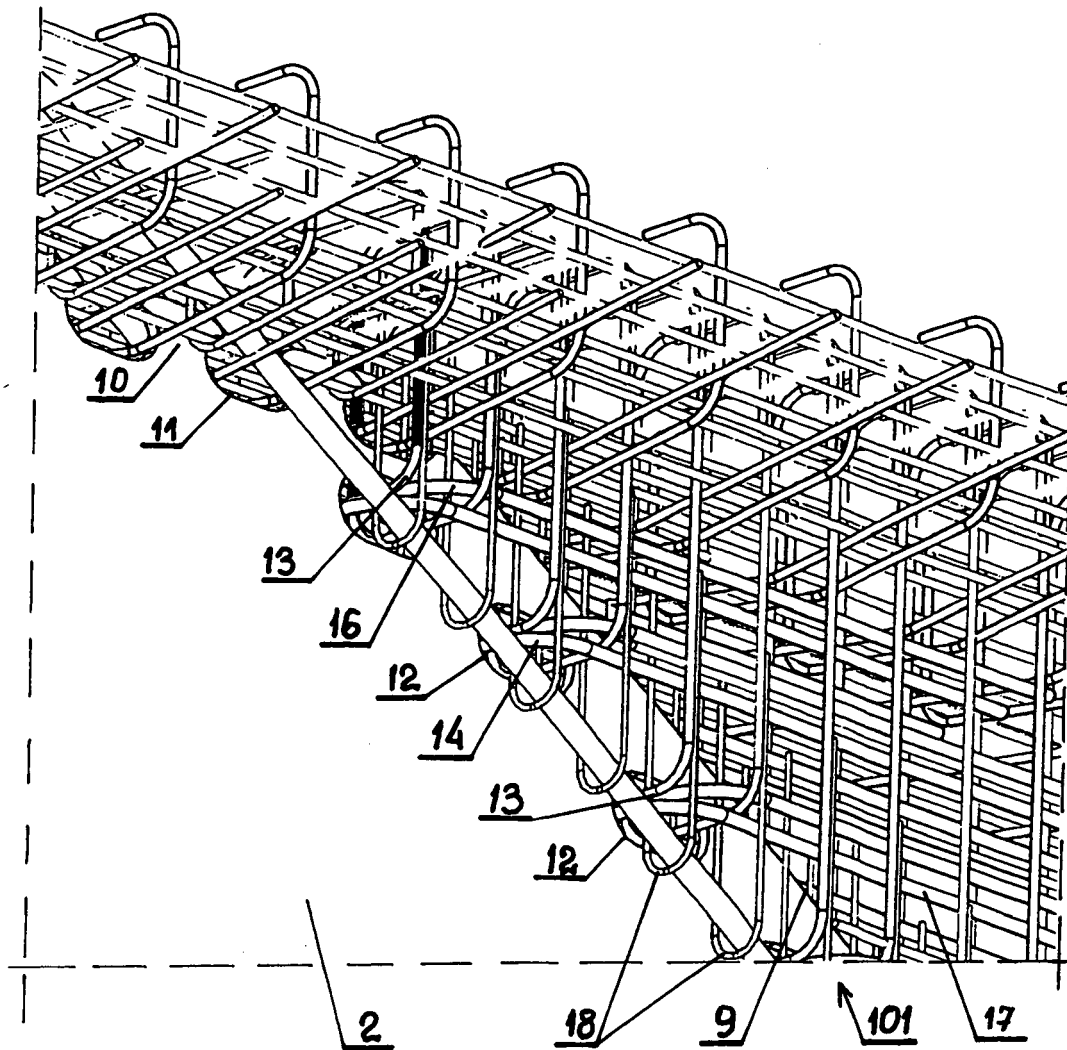


Fig. 7

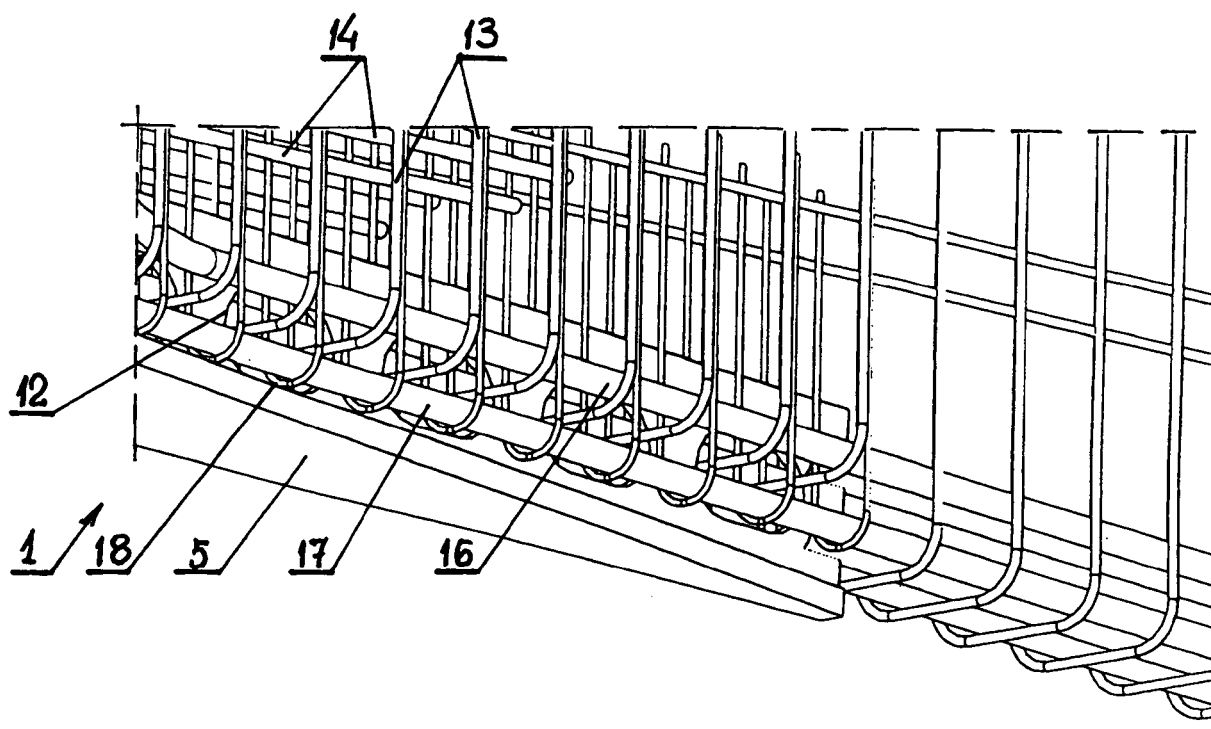


Fig. 8

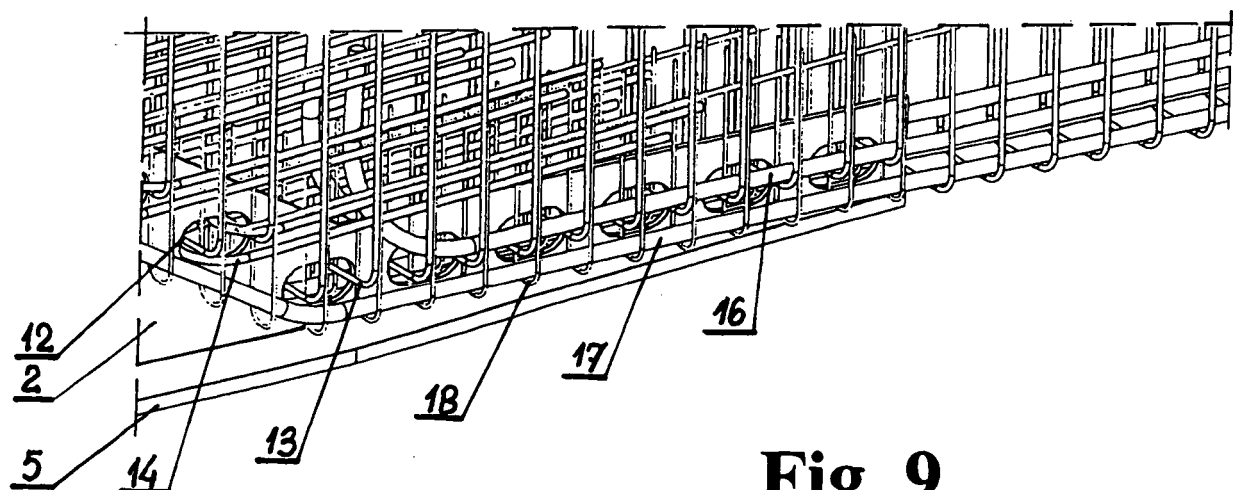


Fig. 9

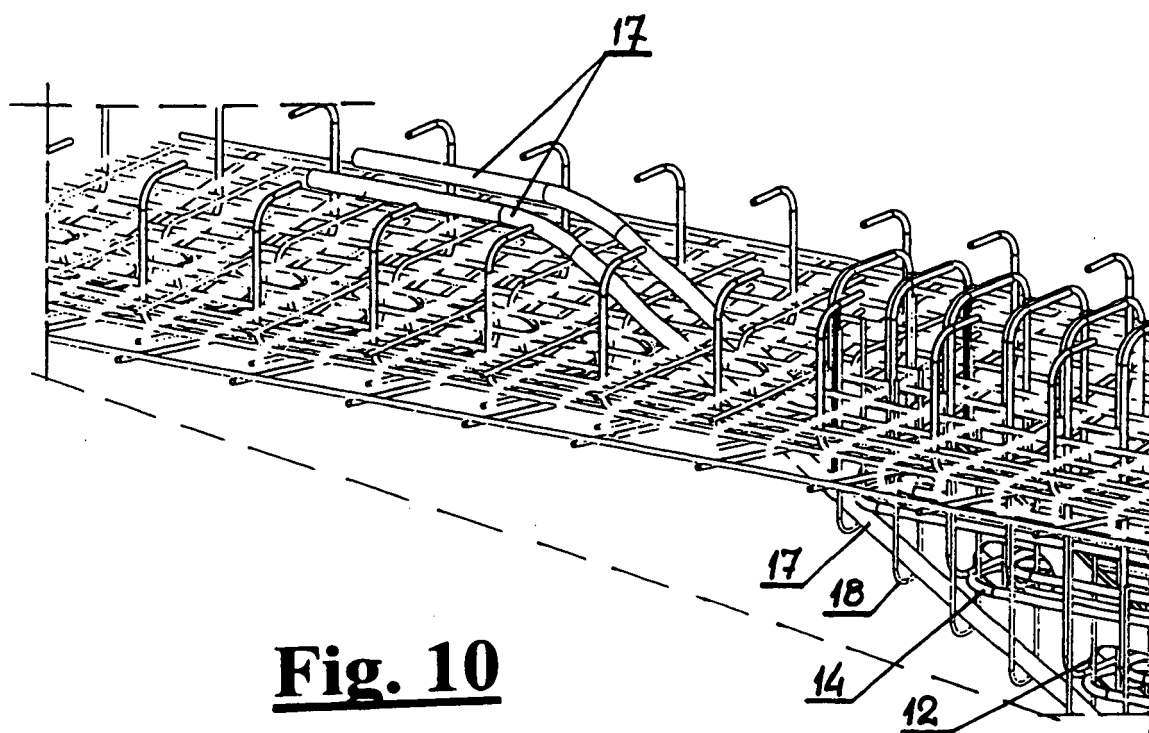


Fig. 10

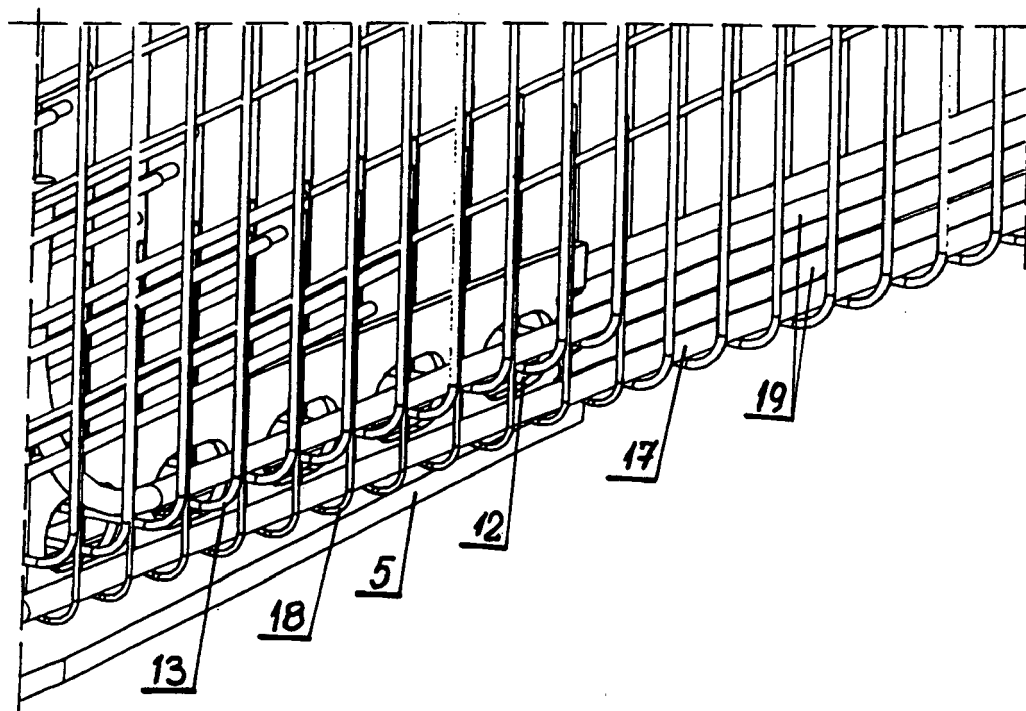


Fig. 11



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Application Number
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Munich		9 May 2017	Saretta, Guido
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