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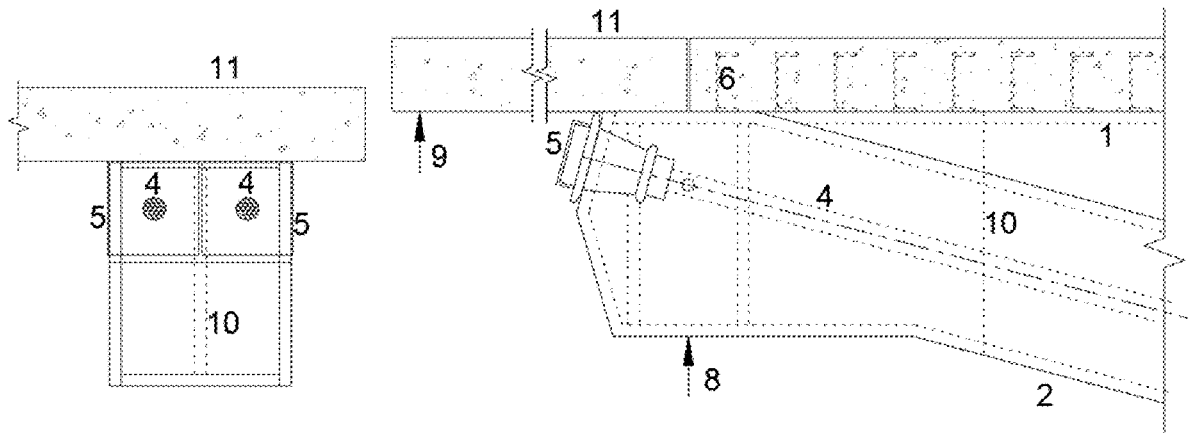
(19) **United States**(12) **Patent Application Publication**
Singh(10) **Pub. No.: US 2024/0271375 A1**(43) **Pub. Date: Aug. 15, 2024**(54) **COMPOSITE RCC DECK AND
PRESTRESSED PARABOLIC BOTTOM
CHORD UNDERSLUNG OPEN WEB STEEL
GIRDER BRIDGE SUPERSTRUCTURE****E01D 101/26** (2006.01)**E01D 101/32** (2006.01)(52) **U.S. CL.**CPC **E01D 6/02** (2013.01); **E01D 19/125**
(2013.01); **E01D 21/00** (2013.01); **E01D**
2101/26 (2013.01); **E01D 2101/32** (2013.01)(71) Applicant: **Pramod Kumar Singh**, Varanasi (IN)(72) Inventor: **Pramod Kumar Singh**, Varanasi (IN)(21) Appl. No.: **18/238,383**(22) Filed: **Aug. 25, 2023**(30) **Foreign Application Priority Data**Sep. 24, 2021 (IN) 202111043274
Mar. 6, 2022 (WO) PCT/IN2022/050200**Publication Classification**(51) **Int. CL.****E01D 6/02** (2006.01)**E01D 19/12** (2006.01)**E01D 21/00** (2006.01)

(57)

ABSTRACT

Composite decks increase bridge strength and stiffness. Prestressed composite open web steel girder has added advantage of high strength cable support. Results of typical 125 m span bridges having heights of 9.0 m, 10.0 m and 12.5 m, and another 50.0 m span and 2.5 m height are given. Member stresses and bridge deflections during erection remained safe. Average steel off take for the 125 m bridge is 2.65 t/m and for the 50 m span bridge it is 1.77 t/m for limiting live load deflection of Span/800. Its reserve strength is 3.2 times service condition live load.

The girders are panel wise workshop fabricated, assembled at site, jacked up or crane lifted to secure over bearings. Connection of the cross members, and onsite deck casting in parts with stage wise bottom chord prestressing is carried out. Short to long span bridges for single or multiple lanes in road, rail, metro rail, and coastal link projects are feasible.



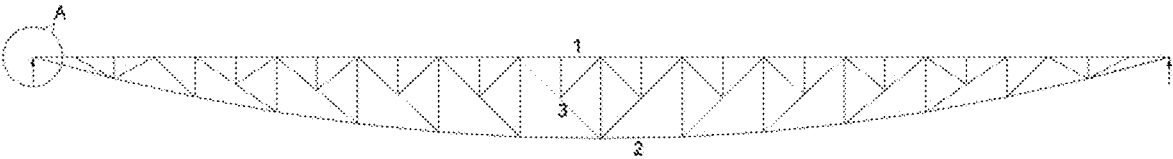


Fig. 1

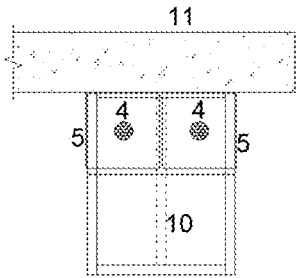


Fig. 2A

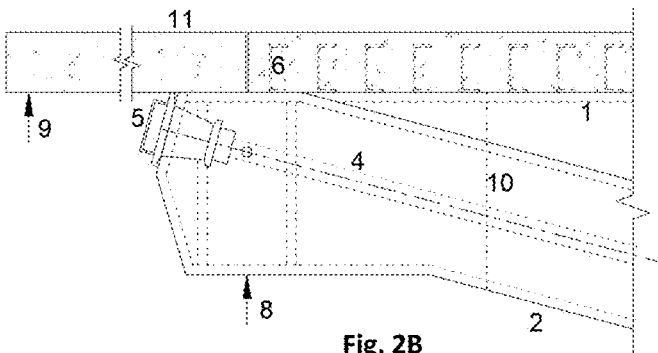


Fig. 2B

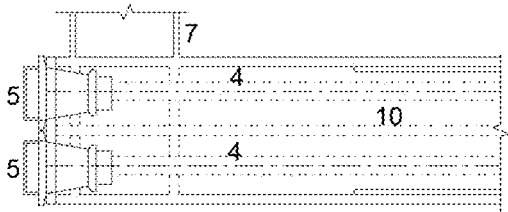


Fig. 2C

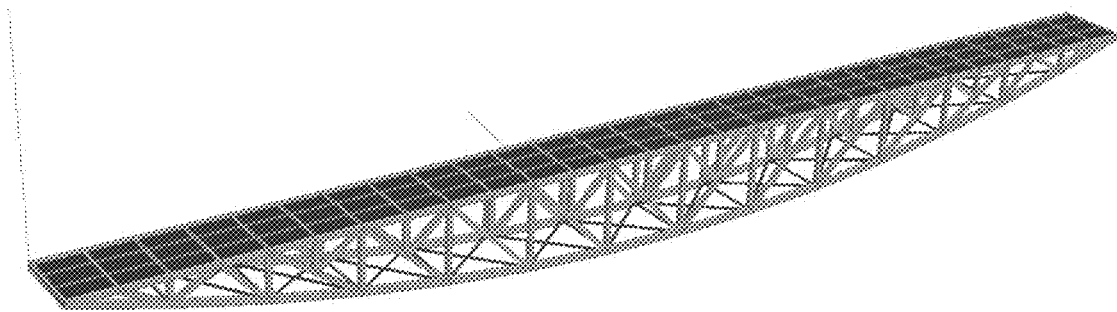


Fig. 3

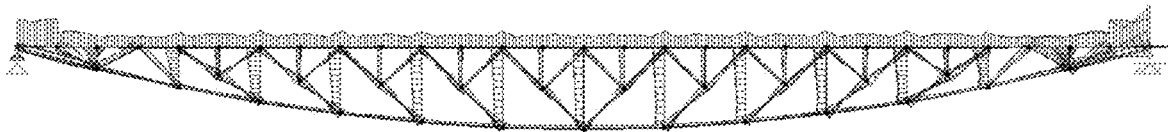


Fig. 4

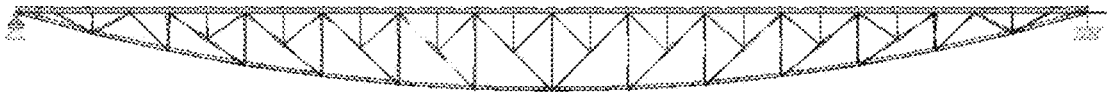


Fig. 5

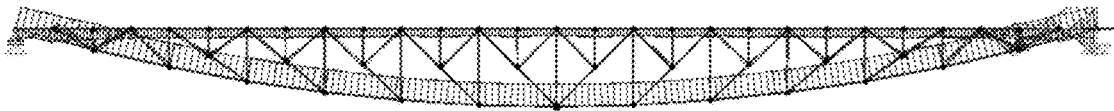


Fig. 6

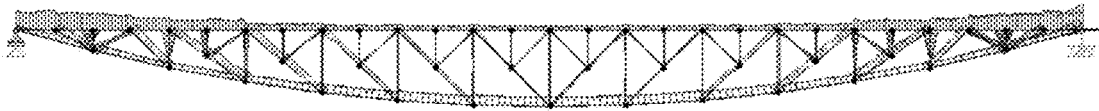


Fig. 7

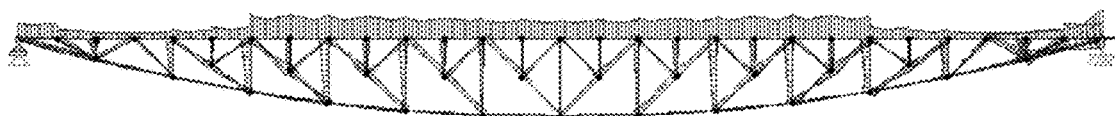


Fig. 8

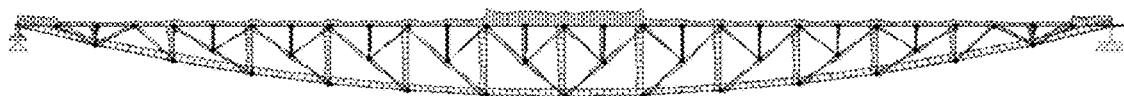


Fig. 9

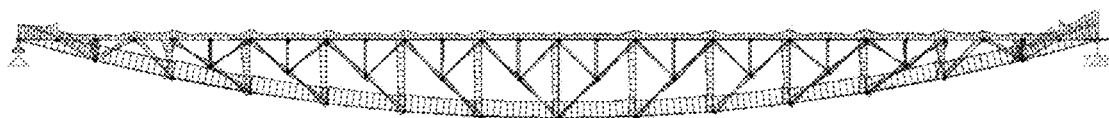


Fig. 10

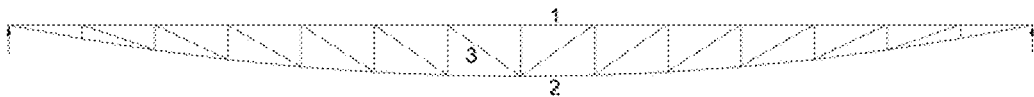


Fig. 11

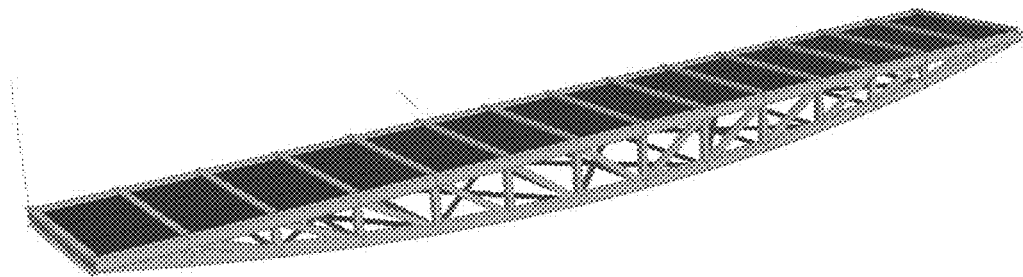


Fig. 12



Fig. 13

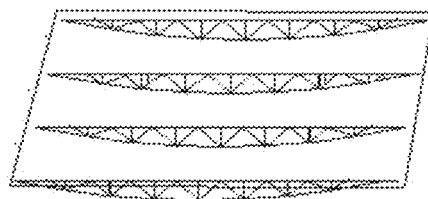


Fig. 14

COMPOSITE RCC DECK AND PRESTRESSED PARABOLIC BOTTOM CHORD UNDERSLUNG OPEN WEB STEEL GIRDER BRIDGE SUPERSTRUCTURE

FIELD OF THE INVENTION

[0001] The invented 'Composite RCC deck and prestressed parabolic bottom chord underslung open web steel girder bridge superstructure' falls in the area of Bridge Engineering in Civil Engineering. The short (10 m) to long (200 m) span superstructures can be used for infrastructure projects related to single or multiple lane road, rail, metro rail, fly over and sea link.

BACKGROUND

[0002] In road, rail and metro rail like transportation systems, bridges are frequently required to cross rivers, as flyovers and sea links etc. For bridges high tensile strength (HTS) steel cables are very economical, using which long span suspension bridges, cable stayed bridges, and more recently stressed ribbon bridges are constructed. However, HTS cables are very flexible and this results in structural disadvantage in the bridge.

[0003] Using shear connectors, when RCC deck slab is made composite with the top chord of an under slung open web steel girder bridge superstructure, its buckling is prevented and strength and stiffness of the bridge significantly increase. Prestressing of the bottom chord, apart from inducing favourable pre-compression in the deck slab, counters its tension due to the applied loads, and it also exerts balancing

constructions may be planned as parallel activities reducing the construction time and cost. It was also aimed to provide a bridge superstructure solution of this kind, which is suitable for short spans (10 m), as well as for long spans (200 m), for single or multiple lane road, rail, metro rail, fly over and projects like coastal links.

SUMMARY OF THE INVENTION

[0005] Typical design and approximate erection stage analysis examples of the prestressed composite bridge for 125 m span and 50 m span are given. While girder stresses under all erection stages are low and safe, member stresses under Serviceability Limit State (SLS) condition are also very safe, as the limiting deflection in SLS condition is governing.

[0006] Maximum deflections under SLS condition for 2-lanes of class-A IRC loading is 155.6 mm with 2.65 t/m average steel off take for 125 m span, and 57.6 mm with 1.77 t/m average steel off take for 50 m span bridges.

[0007] Due to low SLS condition stresses, conservative reserve strength of the bridge beyond SLS condition up to yield condition for the 125 m span bridge is 3.2 times the live load in SLS condition, and for the 50 m span it is 2.8 times. Therefore, design and construction methodology of this type of bridge supported with design guidelines as per existing codes of practice is invented.

[0008] Summary of design and erection stage analysis results for the 125 m and 50 m span bridges in terms of steel off take, member stresses, prestress applied and deflection under live load are given in table-1.

TABLE 1

Design and erection stage analysis results						
Span (Height)	Prestress (kN) - as per FEM	Member stress (N/mm ²)		Structural steel off take (t)	Deflection under LL (mm)	Permissible deflection under LL (mm)
		Top chord	Bottom chord			
125 m (9 m)	2 × 9100 (4 × 27T15)	99.2 (C) (support)	95.5 (C) (support)	331 (2.65 t/m)	151.3	156.2
125 m (10 m)	2 × 8500 (4 × 27T15)	72.1 (C) (support)	73.1 (C) (support)	310 (2.48 t/m)	135.5	156.2
125 m (12.5 m)	2 × 8200 (4 × 27T15)	63.1 (C) (support)	65.4 (C) (support)	299 (2.40 t/m)	140.1	156.2
50 m (2.5 m)	2 × 4500 (2 × 27T15)	22.7 (C)	-8.3 (T)	88.5 (1.77 t/m)	57.6	62.5

upward thrust. This type of bridge using HTS cables in the bottom chord, is invented for its high strength. Bottom chord profile of the bridge, if made parabolic (polygon shaped), results in its uniform tension under uniformly distributed load due to self-weight or live load, which facilitates its prestress. Thus, 'Composite RCC deck and prestressed parabolic bottom chord underslung open web steel girder bridge superstructure', henceforth referred to as 'the prestressed composite bridge' is invented.

Objectives of the Invention

[0004] It was aimed to invent a robust prestressed composite bridge superstructure, which has high strength, low structural steel consumption, low cost, high reserve strength and easy erection, where substructure and superstructure

[0009] From the results it is seen that the prestressed composite bridge superstructures are economical, stiff, and have high reserve strength.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The above and still further features and advantages of embodiments of the present invention will become apparent upon consideration of the following detailed description of embodiments thereof, especially when taken in conjunction with the accompanying drawings, and wherein:

[0011] FIG. 1 shows line diagram of the girder where top chord (1), bottom chord (2) and web members (3) are shown. Cable anchorage details at 'A' are shown in FIG. 2. The 27T15 standard cables (4) and anchorages (5) are shown within and aligned along bottom chord. The composite RCC

deck is cast over top chord, supporting cross girder and stringer beams, using shear connectors (6). End cross girder (7) connects the two main girders. Girders at the ends are supported over bearings (8), and RCC deck slab, beyond the girder, is supported over dirt wall (9). FIG. 3 shows FEM model of the bridge. FIG. 4 shows service load stresses for the prestressed composite 125 m×9 m bridge. FIGS. 5 through 10 show member stresses during corresponding construction stages 1 through 6. Line diagram (FIG. 11), 3-d FEM model view (FIG. 12), and Live Load axial stresses (FIG. 13) for the 50 m×2.5 m bridge are shown. A line sketch for 50 m×23 m superstructure arrangement is given in FIG. 14.

[0012] For better comprehension, figure titles and brief descriptions are also given in Table-2.

TABLE 2

Figure title and brief description		
Fig. no	Title	Brief description
125 m × 9 m case:		
1		2-d line sketch of the girder
2	Anchor details	2 × 27T15 anchorage detail
3	FEM model	3-d view of super structure
4	Stress diagram for service condition	Mid stress: Top chord-38.1 N/mm ² (C) Bottom chord-19.4 N/mm ² (C)
5	Stress diagram for Stage 1	Max stress: Top chord-31.2 N/mm ² (C) Bottom chord-17.1 N/mm ² (T)
6	Stress diagram for Stage 2	Max stress: Top chord-18.1 N/mm ² (T) Bottom chord-87.6 N/mm ² (C)
7	Stress diagram for Stage 3	Max stress: Top chord-113.2 N/mm ² (C) Bottom chord-55.3 N/mm ² (C)
8	Stress diagram for Stage 4	Max stress: Top chord-106.2 N/mm ² (C) Bottom chord-7.4 N/mm ² (T)
9	Stress diagram for Stage 5	Max stress: Top chord-99.3 N/mm ² (C) Bottom chord-47.7 N/mm ² (C)
10	Stress diagram for Stage 6	Max stress: Top chord-33.4 N/mm ² (C) Bottom chord-95. N/mm ² (C)
50 m × 2/5 m case:		
11	Line sketch	2-d line sketch of the girder
12	FEM model	3-d view of super structure
13	Stress diagram under service load	Max stress: Top chord-22.7 N/mm ² (C) Bottom chord-8.3 N/mm ² (T)
14	Superstructure sketch	50 m × 23 m superstructure arrangement

DETAILED DESCRIPTION OF THE INVENTION

[0013] The headings used herein are for organizational purposes only, and are not meant to be used to limit the scope of the description or the claims. As used throughout this application, the word “may” is used in a permissive sense (i.e., meaning having the potential to), rather than the mandatory sense (i.e., meaning must). Similarly, the words “include”, “including”, and “includes” mean including but not limited to. To facilitate understanding, like reference numerals have been used, where possible, to designate like elements common to the Fig. s. Optional portions of the Figs. may be illustrated using dashed or dotted lines, unless the context of usage indicates otherwise.

[0014] A typical 125 m span and 9 m deep composite prestressed 2-lane open web steel girder bridge is designed for which 2-d line sketch is given in FIG. 1. The top chord consists of 500 mm×500 mm×16 mm box section, the

bottom chord is 500 mm×600 mm×22 mm box section, and the web members have the section of 500 mm×200 mm×16 mm.

[0015] Typical anchorage system at the supports of the under slung bridge superstructure is shown in FIG. 2. E410 grade steel having 410 N/mm² yield stress is used in the end panels for high strength in the anchorage, support and the transition zones. Two number 27T15 cables for the 125 m span case for each girder are used. Loads from the cable anchors, apart from the top and bottom plates, are transmitted through the extended two number E410 grade bottom chord side plates and one number central stiffening plate (10). The anchorage system must be designed with high fos, shop fabricated, and tested before assembly.

Analysis:

[0016] Using FEM software, the superstructure is analyzed as space frame with the composite deck modeled as plate elements, for which the model is shown in FIG. 3. It is analyzed for two lanes of Class A (IRC:6-2017) load and the low member axial stress diagrams in service condition are shown in FIG. 4.

[0017] Maximum deflection of the bridge under live load is 155.6 mm, which is within the prescribed limit of Span/800. Average steel off take of the bridge superstructure is 2.65 t/m, which is significantly lower than similar open web steel girder superstructure steel offtake. Parallel 125 m span 10 m deep and 12.5 m deep girder models are also analyzed and the results of the 9 m, 10 m and 12.5 m deep girders are compared.

Erection of the Bridge Superstructure:

[0018] The bridge girder panels may be fabricated in the workshop using welded or HSFG bolted connections. The panels are transported to the site where these are assembled and connected, and the individual girders are lifted to securely placed over the bearings using jacks or cranes or any other suitable device. The cross members for top and bottom chords may be then connected. Deck slab for the superstructure is cast in symmetrical parts using bonding agent and stage prestressing.

[0019] HTS prestressing cables are laid in the parabolic bottom chord. Prestressing of the strands is carried out in stages as per design. Results of the different construction stages for member stresses and maximum deflection are shown in FIGS. 4 through 10 for the 125 m×9 m bridge case.

[0020] Typical example for stage prestressing is given below for the two number 27T15 cables in each bottom chord.

[0021] Stage 1: Launch the girder including cross members, cross girders and stringer beams and suitably apply a prestress of 2000 kN (FIG. 5). Deflection at mid span of the girder in this stage is 17.8 mm (downward).

[0022] Stage 2: Apply additional 2000 kN prestress (FIG. 6). Deflection at mid span of the girder in this stage is 151.7 mm (upward).

[0023] Stage 3: Cast deck slab in 1/5th spans from either end. This stage includes construction load of 5 kN/m². Deflection at mid span of the girder in this stage is 3.5 mm (upward).

[0024] Stage 4: Apply additional 1000 kN prestress after 10 days of concreting in Stage 3 and cast next $\frac{1}{5}^{th}$ spans (11). Deflection at mid span of the girder in this stage is 121.7 mm (downward).

[0025] Stage 5: Apply additional 1000 kN prestress after 10 days of concreting in Stage 4 and cast central $\frac{1}{5}^{th}$ span (11). Deflection at mid span of the girder in this stage is 7.6 mm (downward).

[0026] Stage 6: Prestress by additional 3100 kN force after 28 days of applying SIDL on the deck (11). Deflection at mid span of the girder in this stage is 75.5 mm (upward).

[0027] As an alternative, two stage prestressing, first before deck casting, and second after its hardening may be better.

[0028] Live load is now applied on the bridge. Deflection at mid span of the girder in this stage is 80.5 mm (downward). Additional prestress can be applied in due course of time to make up for time dependent losses etc., reflected in terms of sagging deflection.

[0029] Another typical 50 m span and 2.5 m deep composite prestressed 2-lane open web steel girder bridge is designed (FIG. 11). The top chord consists of 300 mm×300 mm×16 mm box section, the bottom chord is 300 mm×450 mm×22 mm box section, and the web members have the width of 300 mm, thickness of 16 mm and depth of 250 mm.

[0030] FEM model and axial stress diagram in service condition are given in FIG. 12 and FIG. 13, respectively.

Prestress Calculation Using Load Balancing:

[0031] It is assumed that after application of prestress, the girders become horizontal and cables carry total permanent load and half the live load with impact. Finer prestress adjustment for losses etc. may be carried out as required for the final deck profile.

[0032] Taking parabolic bottom chord center as origin, equation for it is:

$$y = ax^2, \text{ or } a = 2.5 / (25 \times 25) = 0.004$$

$$(dy/dx)_{end} = 2ax = 0.008 \times 25 = 0.2 \text{ rad}$$

$$\text{Balancing load} = SW - 750 + \text{Deck} - 2660 + WC - 610 +$$

$$CB - 750 + (LL \text{ with Impact})/2 - 604 = 5374 \text{ kN}$$

$$\text{Prestress required per girder} = 5374 / (2 \times 2 \times 0.2) = 6797 \text{ kN}$$

Provide 2 no. 19T15 (3870 kN) cables.

Pre-Compression in Deck Slab:

[0033] Taking 19T15 cable stressed after deck slab hardening, prestress applied along the two bottom chords:

$$= 2 \times 3870 = 7740 \text{ kN}$$

Vertical component goes to support,

$$\text{and horizontal force,} = 7740 \cos 11.4 = 7587 \text{ kN}$$

$$\text{Areas (Cm}^2\text{); Top chord} = 192,$$

$$\text{Equivalent deck} = 1770, \text{ Bottom chord} = 330$$

-continued

$$\text{Force shared by bottom chord} = (330/2292) \times 7740 \times .98 = 1093 \text{ kN}$$

$$\text{Force taken by RCC deck} = (7740 - 1093) \times 1770/1962 = 5996 \text{ kN}$$

$$\text{Therefore, Axial stress in deck} = 5996000/2125000 = 2.8 \text{ N/mm}^2$$

[0034] Adding tensile strength of concrete say 1.4 N/mm^2 , and keeping cross girder spacing suitably, deck slab can be designed on no-crack basis, which is highly desirable for the composite deck.

[0035] The typical examples of 125 m span, 9 m deep and 50 m span 2.5 m deep, 2-lane highway superstructure girders are optimized to result in steel off take of 331.0 t and 88.5 t, respectively. The maximum deflections due to live load at mid span are 151.3 mm and 57.6 mm respectively for the 125 m and 50 m spans which are within the permissible deflection of Span/800.

[0036] For the 125 m span bridge, the axial member stresses during erection and concreting of the deck are checked with prestressing applied at different stages as per design to be safe. The limiting live load for elastic condition is found to be 3.2 times the SLS live load for the 125 m span, and 2.8 times for the 50 m span, confirming their robustness. In the case of the 125 m span, for parallel 10 m and 12.5 m deep girder examples, steel off takes are 310 t and 299 t, and corresponding live load deflections are 135.5 mm and 140.1 mm, respectively.

[0037] Concrete Grouting: Dead weight of the superstructure is fully supported by the prestress alone with favorable precompression in the RCC deck, and hence, expansive concrete grouting of the box sections is desirable. The Concrete Filled Steel Tube (CFST) now becomes composite, providing additional strength and stiffness to the bridge superstructure.

What is claimed is:

1. A method for prestressed open web steel girder composite bridge superstructure construction, the method comprising:

connecting a composite top chord (1) to a prestressed parabolic (polygon) bottom chord (2) using a plurality of open web members (3);

aligning cables (4) and anchorages (5) within and along the prestressed parabolic bottom chord;

supporting cross girder (7), stringer beams, and composite deck slab using a plurality of shear connectors (6);

connecting end cross girder (7) with at least two main girders, wherein the girders at the ends are supported over bearings (8);

obtaining prestressed parabolic (polygon) bottom chord (2) for an underslung bridge and connected to the top chord (1) for nearly uniform tension under uniformly distributed load to attain a composite prestressed underslung bridge which is conducive to prestress;

the composite prestressed underslung bridge up to a predefined span between 10 m to 200 m; fabricating a plurality of superstructure panels in a workshop, their assembly and connection at site, girder wise launching, followed by on site composite RCC deck slab concreting in symmetrical parts with designed stage wise prestressing, wherein the deck slab for the superstructure is cast in symmetrical parts using bonding agent; and

stage wise prestressing of the bottom chord, from girder lifting stage to bridge commissioning stage, facilitating member stress and bridge deflection management within threshold limits during construction and service life of the bridge.

2. The method as claimed in claim 1, wherein stiffness of the composite deck slab connected to the top chord and strength of high tensile strength cables being provided to the composite prestressed underslung bridge, results in its low deflection, high strength and stiffness, and about three times reserve strength in elastic limit.

3. The method as claimed in claim 2, comprises prestressing of high tensile strength cables laid within the parabolic bottom chord.

4. The method as claimed in claim 1, wherein prestressing of the bottom chord (2) counters tension due to the applied loads and the prestressing of the bottom chord exerts load balancing upward thrust.

5. The method as claimed in claim 1, wherein prestressing of the bottom chord (2) causes longitudinal pre-compression in the deck slab, which may render its design on no-crack basis possible, which is highly desirable for its better fatigue performance.

6. The method as claimed in claim 1, wherein prestress is applied for countering half the live load with impact, reduces curvature and girder flexural stress effect due to live load in the deck slab to half.

7. The method as claimed in claim 1, wherein the bottom chord (2) profile of the bridge, when made parabolic, results in its uniform tension under uniformly distributed load due to self-weight or live load, which facilitates the bottom chord prestress.

8. The method as claimed in claim 1, wherein the pre-defined span is between 10 m to 200 m of the composite

prestressed underslung bridge for single or multiple lanes of road, rail, metro rail, and projects like fly over and sea link.

9. The method as claimed in claim 1, wherein axial member stresses during erection and concreting of the composite RCC deck slab are checked with prestressing applied at different stages as required, to be low and safe.

10. The method as claimed in claim 1, wherein preventing premature buckling failure and increasing its strength and stiffness, using the plurality of shear connectors, whereby RCC deck slab is made composite with the top chord of the bridge.

11. The method as claimed in claim 1, wherein expansive concrete grouting of the box sections, converting these to CFST composite, increases strength and stiffness of the superstructure, apart from corrosion prevention.

12. A prestressed open web steel girder composite bridge comprising:

- a top chord (1) connected to a prestressed parabolic (polygon) bottom chord (2) using a plurality of open web box or CFST members (3);
- a plurality of cables (4) and a plurality of anchorages (5) housed and aligned along the prestressed parabolic bottom chord (2);
- a plurality of shear connectors (6) adapted to support cross girders and stringer beams;
- a plurality of bearings (8) configured to connect end cross girder with at least two main girders; and
- a composite RCC deck slab (7) cast over the top chord (1), cross girder and stringer beam, and longitudinally pre-compressed due to the prestressing allowing its design on no crack basis for its better fatigue performance, wherein the deck slab for the superstructure is cast in symmetrical parts using bonding agent.

* * * * *