CAMBERING AND PRESTRESSING OF STANDARD STEEL GIRDERS ON RAILWAY BRIDGES

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1.0 INTRODUCTION

Indian Railways are having about 1.27 lac bridges out of which about 16000 are steel girder bridges. Mostly all steel bridges of span 30.5 meters and above are of open web type. Open web girders are used as through standard spans of 30.5, 45.7, 61.0 and 76.2 meters. Warren truss (triangulated truss) with vertical members at every panel point is used as standard truss for these girders. As a standard practice camber is provided in steel girder bridges to offset the effect of deflection under moving load. In addition to camber, prestressing of truss members is done to counter the stresses likely to develop under actual loads. This paper briefly summarizes the concepts and the existing design provisions for cambering & prestressing.

2.0 CONCEPT OF CAMBER & PRESTRESSING

2.1 Concept of camber is often not well understood by bridge engineers and it is wrongly considered to give prestressing forces in the members. Actually both the terms are having different meaning and different purposes. To provide camber is a functional requirement to avoid effects of vertical acceleration under moving trains. Camber is given in such a way that sag of floor system is restricted when Live Load passes over the bridge. Maximum deflections under specified live loads are found and are given in the opposite direction during design to work out the cambered lengths of the members. Finally when girder is erected floor system will have upward sag. When train passes over the girder the floor system will become horizontal. This is the ideal condition for which the truss has been analysed.

2.2 In case camber is not provided, the deflected shape of the truss under live loads will create additional stresses in the members. These stresses are called secondary stresses.

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2.3 Prestressing is done intentionally in addition to camber to develop reverse kind of stresses in various members of the truss so that these members remain less stressed under moving loads. No savings of material are intended as the sectional area provided is sufficient to take the design stresses. In fact we can design the girders as cambered with or without prestressing. In case, the girders are designed as cambered with prestressing, the secondary stresses are ignored, thus giving an economical design.

3.0 RELEVANT DESIGN PROVISIONS OF IRS STEEL BRIDGE CODE

3.1 The primary stresses in the design of triangulated structures are defined as axial stresses in members calculated on the assumption that -

a) All members are straight and free to rotate at the joints.
b) All joints lie at the intersection of centroidal axes of the members.
c) All loads including the weight of the members are applied at the joints.

3.2 In practice the assumptions made above are not realised and consequently members are subjected not only to axial stresses but also to bending and shear stresses. These stresses are defined as secondary stresses, and fall into two groups:

a) Stresses which are the result of eccentricity of connections and of off-joint loading generally e.g. loads rolling direct on chords, self weight of members and wind loads on members.

b) Stresses which are the result of elastic deformation of the structure and the rigidity of the joints. These are known as deformation stresses.

3.3 Structures are designed, fabricated and erected in such a manner as to minimise as far as possible secondary stresses. In the case of truss spans, ratios of width of the members (in the plane of distortion) to their lengths between centres of inter-sections may preferably be not greater than 1/12 for chord members and 1/24 for web members, in order to minimize the deformation stresses.

3.4 Secondary stresses which are the result of eccentricity of connections and off-joint loading generally are computed and combined with the co-existent axial stresses, but secondary stresses due to the self-weight and wind on the member are ignored.

3.5 In all cases of truss members deformation stresses described above are either computed or assumed as specified and added to the co-existing axial stresses.

3.6 In non-pre-stressed girders, deformation stresses are assumed to be not less than 16 $^{2}/_{3}$ per cent of the dead load and live load stress including impact.

3.7 In the case of prestressed girders, deformation stresses may be ignored. However, girders are not to be designed for prestressing unless it is assured that the standard of workmanship in the fabrication and erection of girders will be such that correct prestressing can be relied upon.

3.8 The effectiveness of pre-stressing in the web members of spans below 60m (200ft) and in all members of spans below 45m (150ft) is to be ignored. In actual practice, in standard open web girders, the effectiveness of prestressing in all the members, is ignored.

3.9 All open web girders for railway bridges of spans 30.5 m (100ft) and above shall be prestressed.

3.10 Rules for prestressing of open web girders are given in Appendix – A of Steel Bridge Code.

3.11 Beams and plate girder spans upto and including 35.0m need not be cambered.

3.12 In non-prestressed open web spans, the camber of the main girders and the corresponding variations in length of members shall be such that when the girders are loaded with full dead load plus 75 per cent of the live load without impact producing maximum bending moment, they shall take up the true geometrical shape assumed in their design.

3.13 Where girders are prestressed the stress camber change should be based on full dead load and live load including impact.

4.0 CAMBER REQUIREMENTS OF STEEL GIRDERS

4.1 All standard plate girders are of less than 35.0 metre span, hence camber is not provided.

4.2 All open web girders of railway bridges are required to be designed as pre-stressed.

4.3 Dead load camber recorded after assembly and erection should be retained during the service life of girder if there is no distress.

4.4 During technical inspection, camber is checked at every panel point of bottom chords of both truss with the help of dumpy level or precision level, which will facilitate the inspection officials to understand the structural condition.

4.5 As far as possible camber observations are required to be taken at the ambient temperature mentioned in the stress sheet. Details of dead load camber is given in Table 1.0 for open web through girders for guidance.

Table– Design and Dead Load Camber of Through Type Open Web Girders

(a) MBG Loading

SPAN	Condition	L0	L1	L2	L3	L4	L5	Drg. No.
30.5 m	A	0	15.5	23	27	-	-	BA-11341to 57
	B	0	13.5	20	24	-	-	
45.7 m	A	0	23.0	40	55	57	-	BA-11361to 77
	B	0	18.0	32	44	46	-	
61.0 m	A	0	32.5	57	76.5	81		BA-11321to 38
	B	0	24.5	44	58.5	62		
76.2m	A	0	35.0	62.5	88	101	108	*BA-11151*to 68
	B	0	24.0	50.5	58	65	70	

(b) HM Loading

SPAN	Condition	L0	L1	L2	L3	L4	L5	Drg. No.
30.5 m	A	0	13.88	22.87	28.49	-	-	BA-11521 to 38
	B	0	12.16	20.04	24.96	-	-	
45.7 m	A	0	23	34.8	48.6	53.6	-	BA-11501 to 18
	B	0	19.78	29.92	41.79	46.09	-	
61.0 m	A	0	32.75	55.6	74.63	78.12	-	BA-11551 to 68
	B	0	25.93	44.03	59.08	61.85	-	
76.2m	A	0	37.6	67.35	93.29	105.68	114.17	BA-11621 to 39
	B	0	29.07	52.06	72.12	81.7	88.26	

A Design camber value as per camber sheet of fabrication drawing

B Dead load camber value after erection & supporting span on bearings after removing intermediate supports.

Note : All dimensions are in mm

4.6 It is a good practice to draw dead load camber, last inspection camber readings and present recorded readings of each panel points on graph paper with different colour for each girder of bridge to ascertain any loss of camber which will be a permanent record.

4.7 If there is no loss of camber when compared to dead load, camber recorded in bridge register or the last inspection report, it will assure inspecting official that no internal structural change is taking place and structure is not distressed.

4.8 Loss of camber in a girder can be due to:

i) Heavy overstressing of girder or component due to loss of cross section on account of corrosion or increased load than the designed load or due to fatigue of the structure.

ii) Adding on extra dead load on girder such as ballast, extra thickness of road material, service pipelines, etc.

iii) Overstressing of joint rivets i.e. in open web girder at any panel point.

iv) Play between holes and rivet shank on account of elongation of holes or crushing of rivet shanks.

4.9 If any loss of camber is noticed during inspection, following investigation is to be carried out:

1. Camber readings should be verified again at the ambient temperature at which bearings have been centralized during erection. At high temperatures lesser camber values are expected due to longitudinal thermal expansion of girders.
2. Girder should be thoroughly inspected and checked for loose rivets at panel joints or at splices. Also all members should be thoroughly inspected for distortion or deformation.
3. Check whether bearings are frozen.
4. Stress reading of critical members under maximum load should also be taken by strain gauge methods to check if any member is over-stressed.

4.10 Loss of Camber may not actually affect the functionality of bridges, specially if, standard steel girders have been provided. Normally loss of camber should not occur, if the girder has been fabricated & erected as per laid down quality procedures. In order to ensure this, fabrication of all the open web girders is inspected by B&S Directorate of RDSO.

5.0 CONCLUSIONS

5.1 It can be seen that providing camber in open web girder bridges is an important functional requirement. The constant availability of dead load camber during the service life of the bridge is an important parameter to monitor the health of the bridge.

5.2 Standard open web girders are designed as cambered with pre-stressing, thus ignoring the secondary stresses and giving an economical design.

5.3 Quality control during fabrication and erection is an important codal requirement to ensure longer service life of the girders. Therefore, all works of fabrication of open web girders are to be inspected by RDSO.

5.4 Loss of camber in standard open web girder, during service life needs to be analyzed critically before recommending re-girdering or imposing severe speed restrictions.

5.5 The availability of the specified dead load camber after erection is a sign of good workmanship during fabrication and erection.