ज्ञान ज्योति से मार्गदर्शन

To Beam As A Beacon of Knowledge

INSPECTION AND MAINTENANCE OF STEEL GIRDERS













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PREFACE TO THIRD EDITION

Book on Inspection and Maintenance of Steel Girders was first published in the year 1988, second edition brought out in the year of 2003. Due to adoption of new technologies and revision of Codes and Manuals, it was necessary to revise this book. Now the Third Edition is being brought out duly incorporating the various correction slips, RDSO Publication, recommendations of Bridge Standards Committee etc. All the Chapters are thoroughly revised and supplemented with photographs and sketches to make the topics more clear.

It is hoped that this book will fulfil the needs and assist field engineers in enhancing their awareness about the aspects of inspection and maintenance of Steel Bridges.

Suggestions for improvement may be sent to the undersigned.

PUNE
Nov. 2016

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ACKNOWLEDGEMENT TO THIRD EDITION

Since the second edition of this book a lot of technical improvement had been adopted by Indian Railways in fabrication, Inspection, and Maintenance of Steel Girders. Therefore, it was important to thoroughly revise this book. Each and every chapter of this book is revised and rewritten duly incorporating latest changes in the various Codes and Manuals etc. The latest loading standards, steel specifications and uses of HSFG bolts in the Railway girders are added in Chapter 2. Scope of Chapter 3 is enlarged by adding 'H' beam sleepers

Chapter 4 is revised by incorporating, Inspection of Steel Girder, details of Inspection of Steel Girder, Method of Inspection, Important instrumentation for higher axle load and NDT for steel structure. Appurtenances for bridge inspection, arrangements, inspection related to HSFG bolts, corrosion, fatigue, and early steel girders are revised. Inspection of bearing, riveted and welded structure and connection made with HSFG bolts are revised and added. This chapter has been supplemented with two case studies, related with the study on crack members and other related to assessment of fatigue life.

Chapter 5 Maintenance of Steel Girder is provided with maintenance of bearing, latest painting scheme for ordinary and long life painting. A detailed listing of common problems, its causes and remedial actions has been listed out. Repairs related to welded bridge and ROBs are included and two case studies related to replacement of cross girder and other related to replacement of bottom chord and strengthening of girders of ROB are included.

We are thankful to Shri Dadaria, ED/RDSO and Shri V. B. Sood, Director/Steel/RDSO for giving relevant suggestions

and sharing the useful information related to steel girders being used in Indian railways.

Efforts have been made by IRICEN faculty and staff to bring out this new edition as more useful guide for the field engineers. In this process the contribution of Shri Harish Trivedi, Shri Pravin Kotkar, and the DTP by Shri Aman Apradh is most notable.

We are also thankful to Shri C. S. Sharma, Sr. Professor IRICEN and Shri N.K. Khare, Ex. Professor, IRICEN for arranging the DTP work and proof checking. We are also thankful to faculty of IRICEN for giving useful suggestions for improving the presentation of this book.

Above all We are grateful to Shri Vishwesh Chaubey, former Director IRICEN for giving me opportunity and encouragement for the revision and updating of this book.

We are also grateful to Shri N. C. Sharda, Director IRICEN for his encouragement, regular guidance and suggestions, to bring out the book in its present form.

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Professor Bridge
IRICEN

V. N. Sohoni
Sr. Instructor Bridge
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PUNE
Nov. 2016

PREFACE TO THE SECOND EDITION

The book “Inspection and Maintenance of Steel Girders” was first published in 1998. It was very popular among the field engineers and became out of stock in due course of time.

Therefore, the second revised and enlarged edition has been brought out to fulfill the continuous demand for the book. Interalia a new chapter on steel channel sleeper has been added which incorporates details about fixing and inspection of channel sleepers on the steel girder bridges. Although every effort has been made to bring out latest and present the book in error free manner, yet if there is any suggestion or discrepancy, kindly do write to us.

Shiv Kumar
Director
IRICEN

ACKNOWLEDGEMENT TO THE SECOND EDITION

The first edition of the book published in December 1998 was very popular among the field engineers as all aspects concerning inspection, maintenance and understanding of steel girder bridges were well documented in the book. In this book one chapter was devoted on “Bearing for Steel Girder of Track Bridges”. In the meantime, a separate publication exclusively for bridge bearing was available. Its revised and enlarged edition has been published recently. During last 5 years, need has arisen for use of steel channel sleepers on Girder Bridges in place of Bridge Timbers, due to scarcity of wooden sleepers. Different drawings have been issued by RDSO for channel sleepers.

Keeping in view above, in this 2nd and revised edition, chapter on bearing has been deleted and in place of this a new chapter on steel channel sleeper has been added.

Efforts have been made to make the book more useful for the field engineers. In this effort, the IRICEN faculty and staff have contributed immensely, notably among them are Mrs. Gayatri Nayak and Mr. Sunil Pophale. I am grateful to Shri. N. L. Nadgouda, Retired Associate Professor / IRICEN who has contributed immensely in updating and adding new chapter on Steel Channel Sleepers in this book. I am also grateful to Shri. A. K. Gupta, Professor / Track–1 for proof checking and valuable suggestions.

Above all, the author is grateful to Shri. Shiv Kumar, Director IRICEN for his encouragement and guidance in bringing out the publication.

R. K. Yadav
Professor / Track–2
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ACKNOWLEDGEMENT TO THE FIRST EDITION

While covering the subject of steel girders for railway bridges during various courses at IRICEN, the absence of a document covering their technical details including those of inspections and maintenance was acutely felt.

This IRICEN publication is a result of the desire to fill the gap and produce a documentation which would be useful to the Civil Engineers on Indian Railways as more than 90% of long span track bridges are of steel superstructure.

I would be failing in my duty if I do not acknowledge the support of Shri K. T. Wazalwar, Retired Dy.CE (Bridges), Central Railway, Shri V. P. Sambrani, Ex-Professor Bridges/IRICEN and Dr. V. Balakrishnan, Ex-Dean/IRICEN. Shri Anil Padmane was of immense help in preparation of drawings.

Above all the author is grateful to **Shri Vinod Kumar, Director, IRICEN** for his encouragement and advice for improving the document.

N.L.Nadgouda
Associate Professor
IRICEN – PUNE

FOREWORD TO THE FIRST EDITION

Steel Girder Bridges are of great importance to the railway engineers who are engaged in their design, construction and maintenance. A majority of these engineers are concerned with their inspection and maintenance. Trainee officers have often expressed the need for a comprehensive documentation covering these aspects and better understanding of the steel girder bridges. It is hoped that this book will fulfil this need and disseminate the knowledge and experience on this subject to the field officials.

This book has been prepared by Shri N. L. Nadgouda, Associate Professor of this Institute. If there are any suggestions for improving the book or if any error/ discrepancy is noticed in its contents, kindly write to the undersigned.

Vinod Kumar
Director
IRICEN-Pune
Dec. 1998

PREFACE TO THE FIRST EDITION

With such a colossal numbers of railway steel girder bridges on the Indian Railways and that too with so many varieties in all respects, it is imperative to have a detailed and exhaustive technical knowledge about these structures. Such knowledge will enable purposeful inspection and follow up action to ensure maximum possible life of these costly assets.

To impart this detailed knowledge about the railway steel girder bridges to the railway engineers, efforts have been made in this book to enable them to know and become fully conversant with various aspects of inspection, maintenance and repairs of these structures. Various directives / instructions issued from time to time as well as the provisions contained in the Indian Railways Bridge Manual, 1998, have been kept in view while compiling this book.

It is hoped that this compact literature which will serve to supplement the Lecture Notes for officers attending courses at IRICEN, will also immensely benefit the concerned railway engineers in the field.

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LIST OF ABBREVIATIONS

ABE	Assistant Bridge Engineer
ADEN	Assistant Divisional Engineer
BBJ & Co	Braith Waite Burn and Jessop Company
BF	Braking Force
BFR	Bogie Flat type for Rails
BG	Broad Gauge
BGBL	Broad Gauge Branch Line
BGML	Broad Gauge Main Line
BM	Bending Moment
BR	Bridge Rules
BRI	Bridge inspector
B&S	Bridge and Structure
BSC	Bridge Structure Committee
C	Centigrade
CAD	Computer Aided Design

CAO	Chief Administrative Officer
CBE	Chief Bridge Engineer
CC	Cement Concrete
CC Crib	Christ Church Crib
CDA	Coefficient of Dynamic Augment
CE	Carbon equivalent
CH Girders	Calendar Hamilton Girders
cm	centimetre
CO_2	Carbon dioxide
CRN	Condition Rating Number
CRS	Commission of Railway Safety
C/S	Correction Slip
DA	Dynamic Augment
DEN	Divisional Engineer
DFC	Dedicated Freight Corridor
DFT	Dry Film Thickness
DL	Dead Load
DPT	Dry Penetrant Test
DTI	Direct Tension Indicator
Dy.CE	Deputy Chief Engineer
ECoR	East Coast Railway
ERC	Elastic Rail Clip
EUDL	Equivalent Uniformly Distributed Loads
FOB	Foot Over Bridge

gms	grams
GI	Galvanized iron
g/m^2	gram / square meter
GMT	Gross million tonne
GRSP	Groove rubber sole plate
HAZ	Heat affected zone
HML	Heavy Mineral Loading
HDPE	High Density Polyethylene
HSFG	High Strength Friction Grip Bolt
IRC	Indian Road Congress
IRS	Indian Railway Standard
IRBM	Indian Railways Bridge Manual
IRICEN	Indian Railways Institute of Civil Engineering
IRPWM	Indian Railways Permanent Way Manual
ISHB	Indian Standard Heavy Weight Beams
ISMC	Indian Standard Medium Channel
JE	Junior Engineer
kg/cm^2	kilogram / square centimetre
kg/m^2	kilogram / square metre
KK	Kothavalasa–Kirandul line of Waltair Rly. Division of East Coast Railway Zone.
km	Kilometre
kmph	Kilometre per hour
kN	Kilo Newton

kN / m	Kilo Newton / meter
kN / m^2	Kilo Newton / square meter
KRCL	Kokan Railway Corporation Ltd.
LG	Light Gauge
LL	Live Load
LF	Longitudinal Force
LWR	Long welded rail
m	Metre
mm	Millimetre
MBG	Modified Broad Gauge
MG	Meter Gauge
MGML	Meter Gauge Main Line
MMAW	Manual Metal Arc Welding
MMG	Modified Meter Gauge
MPI	Magnetic Particle Inspection
Mpa	megapascal
MS	Mild steel
NDT	Non Destructive Testing
NG	Narrow Gauge
NRS	Numerical Rating System
ODC	Over Dimension Consignment
OHE	Over Head Equipment
ORN	Overall Rating Number

OWG	Open Web Girder
P.way	Permanent Way
PG	Plate Girder
PSC	Pre-stressed Concrete
PTFE	Poly Tetra Fluoro Ethylene
R	Revised British specifications
RBG	Revised Broad Gauge
RCC	Reinforced Cement Concrete
RDSO	Research Design & Standard Organisation
RF	Racking Force
RFFS	Rail free fastening system
RH Girder	Restricted Height Girder
RL	Rail Level
ROB	Road Over Bridge
RSJ	Rolled Steel Joint
RUB	Road Under Bridge
SAW	Submerged Arc Welding
SE	Section Engineer
SECR	South East Central Railway
SF	Seismic Force
SF	Shear Force
SGCBP	SGCI Canted Bearing plate
SGBP	Spheroidal Graphite Bearing Plate
SGCI	Spheroidal Graphite Cast Iron insert

S-N	Stress Cycles - Number of times
sqcm	Square centimetre
SS	Stainless steel
SWR	Short Welded Rail
Sr.DEN	Senior Divisional Engineer
t	tonnes
t / m	tonnes / meter
UIC	International Union of Railways
UNR	Unique Rating Number
USFD	Ultrasonic Flaw Detector
ZTLF	Zero toe load fastener
m	Micron
%	Percentage
∅	Diametre

CHAPTER 1

STEEL GIRDER IN INDIAN RAILWAYS

1.0 INTRODUCTION

Number of bridges on Indian Railways are to the tune of about 1.31 lakhs belonging to the various types and lengths and in different categories. The criteria for bridges were different depending on the technology and material available in earlier days. Broadly speaking, the bridges in the early days of the railway system were mostly based on steel structures shipped from British Railways to India.

The bridge superstructures in the form of steel girders are either (1) beam type - (plate girders) or (2) truss type (open web). The metal used for the fabrication of girders up to1885 was mostly wrought iron. These girders were either fabricated in England or released from British Railways and transported to India by ship and after due modifications in railway workshops in India were placed in line. Since these were shipped from England to India, the dispatch list accompanying the material was named as "Shipping list" which nomenclature holds good even today for dispatch list of material accompanying the girders from railway workshops to various sites.

Some of the early workshops known as Girder Fabrication Workshops were established at Manmad and Mugalsarai. The transhipped girders and structures were strengthened/ modified in these workshops to suit the extant loading standard and dimensions and put in the road wherever needed.

As the steel technology developed over the years and as the railways began expanding in a big way especially after independence in 1947 a dire need was felt to undertake fabrication of these girders on a huge scale during the successive five year plans for various new construction lines as well as regirdering programmes. With this in view the fabrication of these steel girders was undertaken in railway workshops at Manmad, Mugalsarai and other railway workshops. After 1960 these workshops started fabricating open web girders also. As on date railway workshops fabricate spans ranging from 9.15m length to 76.2m length, (9.15, 12.2, 18.3, 24.4m spans being plate girders and 30.5m, 45.7m, 61.00m and 76.2m spans being open web through girders as also 30.5m underslung deck girders).

In addition a few spans of 91.4m and 122.2m have been fabricated and erected by M/s. BBJ & Co. of Calcutta. Civil Engineering Workshop Manmad had also fabricated 3 nos. 122.2m welded open web through spans, for Konkan Railway Corporation in the year 1995.

After 1980 welded construction is being adopted for fabrication of both plate girders (open deck) and composite girders (ballasted deck) of track bridge. Steel being an ideal metal for fabrication of railway bridge girders due to its tensile and compressive strengths being more or less equal, it is extensively used for railway bridge girders. Moreover before final failure, it generally gives sufficient warning to the maintenance engineer in the form of loss of camber, thus avoiding sudden failure.

1.1 TYPES OF STEEL GIRDERS

In the early days, the railway track bridge- steel girders were of the following types :

1) Duplicated channels with longitudinal sleepers to carry the track.
2) Duplicated beams with cross sleepers to carry the track.
3) Wide flange beam girders.
4) Fish belly type girders, single or duplicated, called beams of uniform strength.
5) Pin connected triangulated type--Single or duplicated.
6) 'N' type open web deck girders
7) 'N' type semi-through girders
8) HOWE type through truss
9) PRATT type through truss
10) Camel back truss
11) Baltimore through truss
12) Warren truss
13) K - truss
14) Through / Pony / Deck Truss

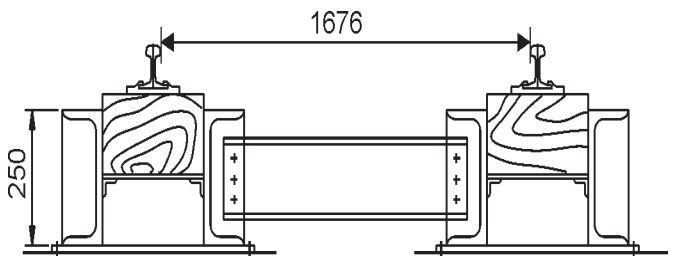


Fig 1.1 Duplicate channel girder

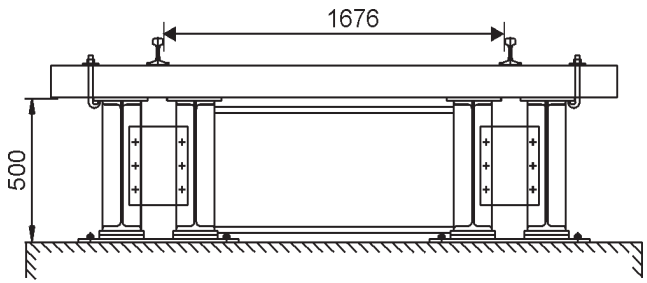


Fig. 1.2 Duplicate beam with cross sleepers (for span upto 3.6m)

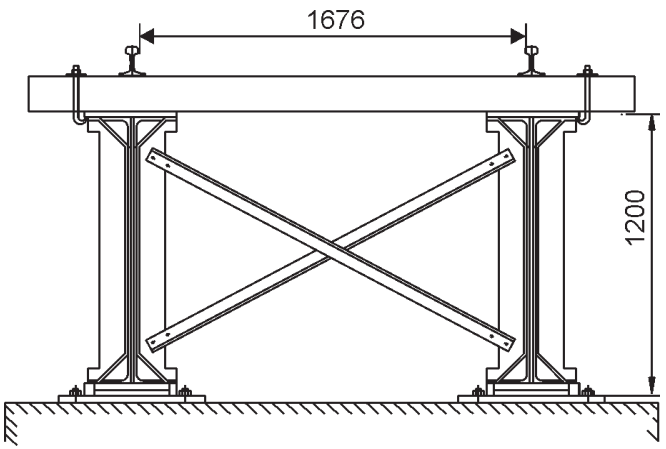


Fig. 1.3 Wide flange beam girder

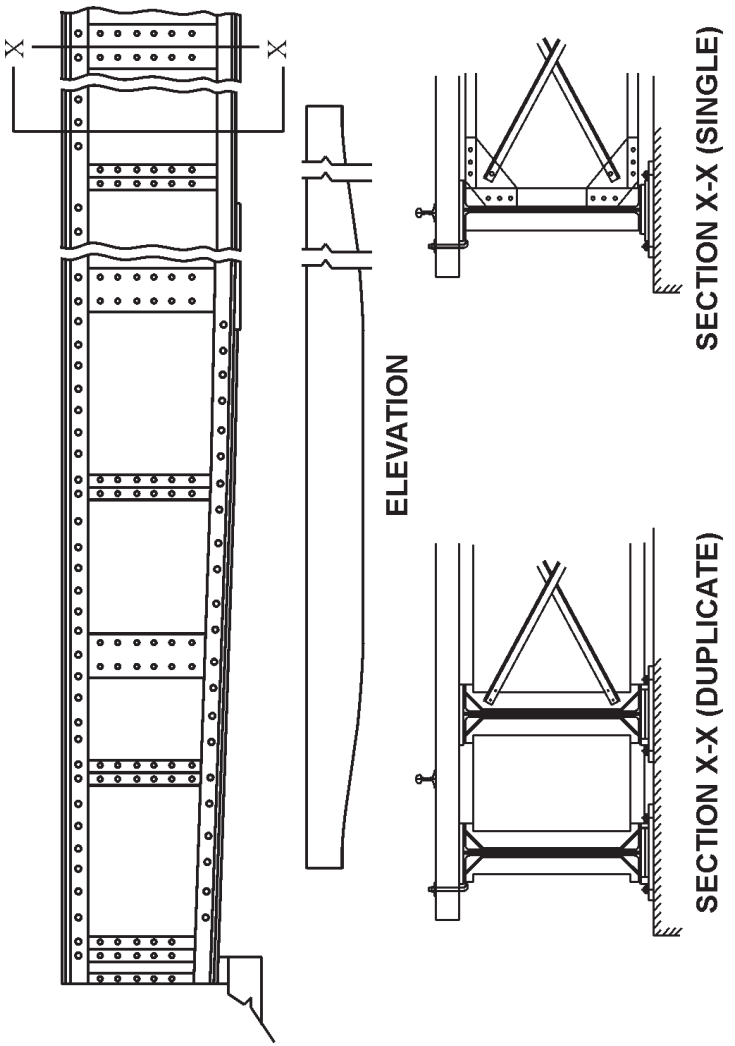


Fig. 1.4 Fish belly girder (Single or duplicate)

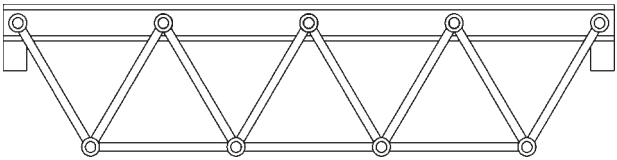


Fig. 1.5 Pin connected triangulated truss

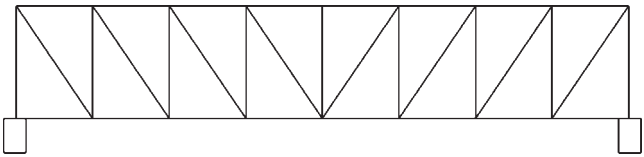


Fig. 1.6 'N' Type Truss

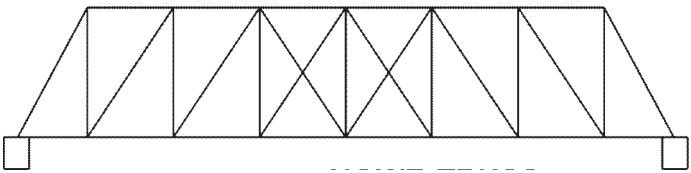


Fig. 1.7 Howe truss

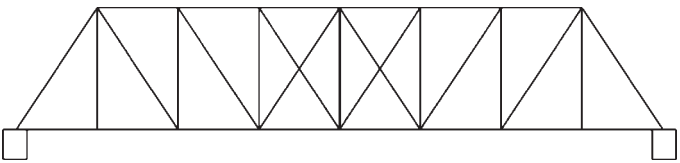


Fig. 1.8 Pratt Truss

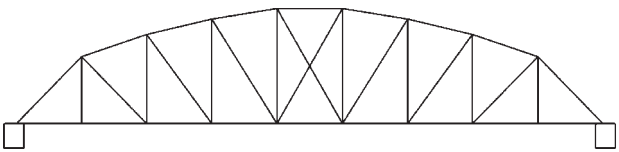


Fig. 1.9 Camel back truss

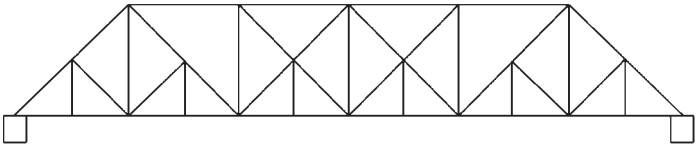


Fig. 1.10 Baltimore truss

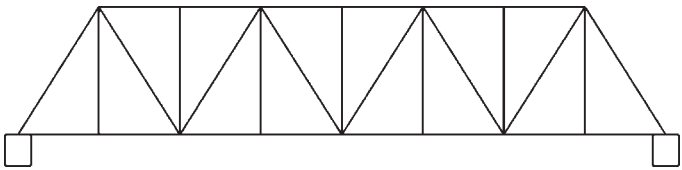


Fig. 1.11 Warren Truss

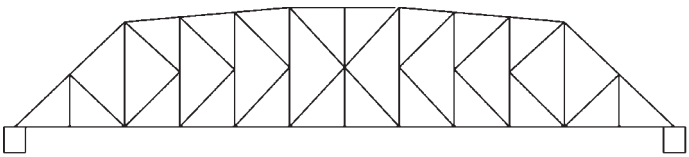


Fig. 1.12 K truss

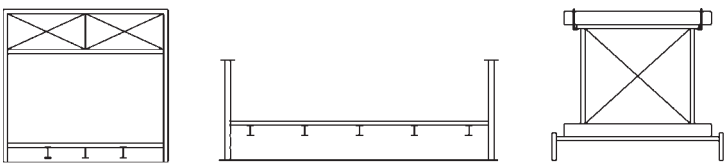


Fig. 1.13

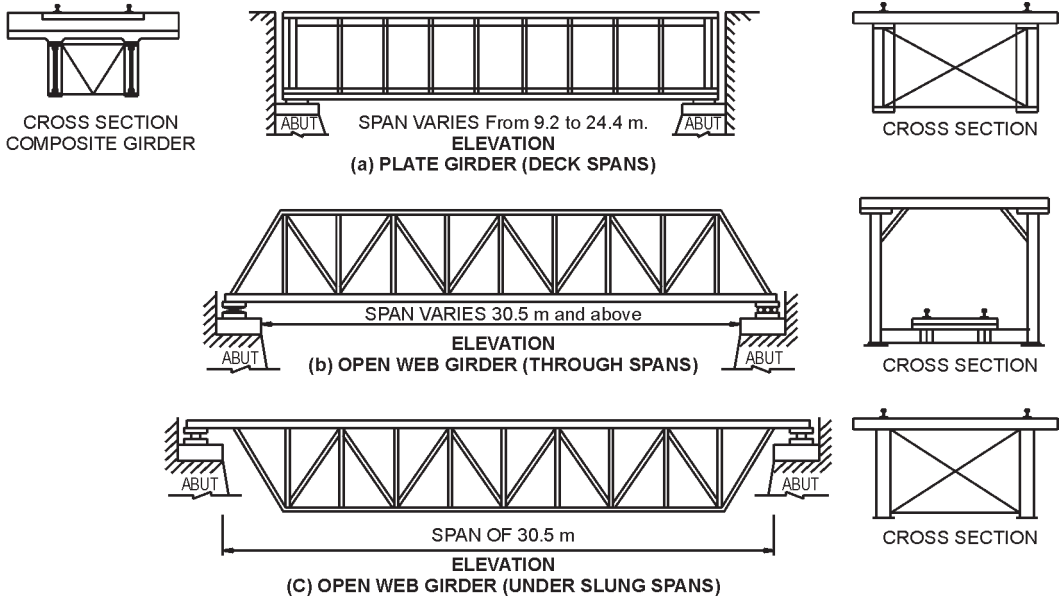


Fig. 1.14 Standard track bridge steel girders (BG)

1.2 CLASSIFICATION OF STEEL BRIDGES

After 1960 railway track bridge girders were standardized as plate girders ranging from 9.2m to 30.5m spans deck type and warren type trusses for 30.5m to 76.2m for through spans and 30.5m underslung spans. Details of drawings for these standard girders are as per Table No. 1.1 A, 1.1 B, 1.1 C, 1.1 D, 1.1E, 1.2, 1.3, 1.4, 1.5 A, 1.5 B, 1.5 C, 1.6 A, 1.6 B, 1.6 C and configurations of Broad Gauge girder are shown in Fig. 1.14

Railway bridge steel girders are classified as follows :

1.2.1. According to function

(a) Track bridges (for rail vehicles/rolling stock)
   i) Over rivers/Nullahs/Canals
   ii) Over valleys (viaducts)
   iii) Over railway tracks (flyover).
   iv) Over the road (Road under bridge).

(b) Road over bridge - Over railway tracks (Road passing on top).

(c) Rail cum road bridge - (Over river) may have common deck or separate deck.

(d) Foot over bridge (FOB) - On station platforms/ across yards.

(e) Pipeline Bridge - For pipeline crossing the railway tracks.

1.2.2 According to form

(a) Steel plate girders (Deck type).

(b) Steel composite girders (for ballasted deck).

(c) Steel open web truss girders (through or underslung spans)

1.2.3 According to the level of the floor carrying the track

(a) Deck type - Track carried on top booms/flanges

(b) Semi-through type (non-standard) - Track carried by rail bearers and cross-girders without top bracing system.

(c) Through type - Track carried by rail bearers and cross girder with top bracing system.

1.2.4 According to structural characteristic

(a) Simply supported

(b) Continuous

1.2.5 According to type of service

(a) Permanent (standard spans)

(b) Temporary (RH girders/relieving girders and Calendar Hamilton Girders)

1.2.6 According to type of construction

(a) Rivetted

(b) Welded

(c) Pin connected (non-standard)

1.2.7 According to railway gauge

(a) Broad Gauge (B.G.) 1676 mm.

(b) Metre Gauge (M.G.) 1000 mm.

(c) Narrow Gauge (N.G.) 762 mm.

(d) Light Gauge (L.G.) 610 mm.

1.2.8 According to standard of loading

(a) For Broad Gauge

1) BGML (Main Line)
2) BGBL (Branch Line) standard
3) HM Loading Standard (Heavy Mineral)
4) RBG Loading of 1975 (Revised Broad Gauge) standard
5) MBG Loading of 1987 (Modified Broad Gauge) standard
6) 25 t Loading - 2008
7) DFC Loading

(b) For Metre Gauge

1) MGML (Main Line) standard
2) MMG of 1988 (Modified Metre Gauge) standard.

Table : 1.1 A
RBG Plate girder rivetted type (BG)

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abut-ment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	9.15 m	Plate Girder	BA-11072	10000	10200	1850	1062	3.20	0.46	10300	1424	1336
2	12.2 m	Plate Girder	BA-11073	13100	13300	1850	1312	9.54	0.47	13400	1674	1585
3	18.3 m	Plate Girder	BA-11074	19400	19650	1830	1876	20.30	0.47	19800	2270	2188
4	24.4 m	Plate Girder	BA-11075	25600	26050	1980	2104	33.56	0.54	26200	2484	2416
5	30.5 m	Plate Girder	BA-11076	31900	32450	2300	2588	59.80	1.43	32600	3135	2977

Table : 1.1 B

MBG Plate girder welded type (with intermediate stiffener, bracings, splice joint rivetted)

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	12.2 m*	Plate Girder	B -16012	13100	13300	1850	1285	9.93	0.397	13420	1789	1700
2	18.3 m	Plate Girder	B -16013	19400	19670	1830	1898	23.81	0.498	19800	2394	2307
3	24.4 m	Plate Girder	B - 16005	25600	26050	1980	2120	44.298	0.836	26200	2610	2526

*Span 12.2 m span Drawing No. 16012 is suitable for 25t Loading - 2008.

Table : 1.1 C

HM Plate girder welded type (with intermediate stiffener, bracings, splice joint rivetted)

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	12.2 m*	Plate Girder	BA -16007	13100	13300	1850	1456	10.332	0.399	13420	1778	1871
2	18.3 m	Plate Girder	BA -16008	19400	19670	1900	1930	27.55	0.572	19860	2420	2336
3	24.4 m	Plate Girder	BA - 16006	25600	26050	1980	2356	55.5	2.98*	26200	3116	2747

For span 24.4m Drawing No. BA-16006 Rocker and Roller bearings are provided.
Weight given is of rocker - roller bearing.

Table : 1.1 D
25t Plate girder welded type
(intermediate stiffener, bracings, splice joints are connected by HSFG bolts)

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	12.2 m	Plate Girder	B - 16014	13100	13300	1850	1309	13.89	0.424 *	13400	1752	1726
2	18.3 m	Plate Girder	B - 16015	19400	19650	1850	1910	27.28	0.681 *	19800	2364	2325
3	24.4 m	Plate Girder	B-16016/R	25600	26050	1850	2289	48.49	1.11 **	26200	2782	2688

* For span 12.2m & 18.3m Sliding Bearings or Elastomeric Bearings can be provided. Weight shown above is for Sliding Bearing. Weight for Elastomeric Bearing is 0.7984 and 0.942 respectively for 12.2m and 18.3m span.

** For Span 24.4m only Elastomeric Bearings are provided and the weight shown is for same only.

Table : 1.1 E

DFC (32.5t) Plate girder welded type (intermediate stiffener, bracings, splice joints are rivetted)

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	12.2 m	Plate Girder	B - 16017	13100	13300	1850	1464	12.603	0.399 *	13420	1986	1879
2	18.3 m	Plate Girder	B - 16018	19400	19670	1900	1930	30.10	0.498 *	19800	2420	2336
3	24.4 m	Plate Girder	B - 16019	25600	26050	1980	2330	53.184	3.340 **	26200	3110	2721

* For span 12.2m & 18.3m Sliding bearings are provided and weight shown above is for same only.

** For Span 24.4m Rocker and Roller bearings are provided and the weight shown is for same only.

Table : 1.2 : MBG Plate girder welded type (BG)
(with intermediate stiffener, bracings, splice joint rivetted)

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	12.2 m	Plate Girder	B - 1528	13100	13300	1850	1312	8.055	0.460	13400	1674	1585
2	18.3 m	Plate Girder	B - 1529	19400	19650	1830	1876	17.810	0.410	19800	2270	2188
3	24.4 m	Plate Girder	B - 1555	25600	26050	1980	2104	34.900	2.100	26200	2484	2416
H.M. Loading (BG)												
1	24.4 m	Plate Girder	BA-16006 & BA-16006/1	25600	26050	1980	2104	55.500	2.970	26200	2484	2416

Table : 1.3: Open web girder (BG) rivetted type RBG standard (suitable for MBG loading)

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	30.5 m	Open Web Through	BA-11341	31926	32460	5180	7671	61.49	2.08	32600	1549	1232
2	30.5 m	Open Web Under Slug	BA-11401	31900	32450	2300	4959	43.9	1.75	32600	1558	5332
3	45.7 m	Open Web Through	BA-11361	47240	47850	5180	7763	111.45	3.14	48150	1603	1297
4	61.0 m	Open Web Through	BA-11321	63000	63700	5500	9605	191.523	4.006	64000	2082	1777
5	76.2 m	Open Web Through	BA-11151	78800	79600	5500	11240	290.56	5.042	79900	2102	1777

Table : 1.4A Open web through girder welded type for MBG loading. All through spans members are having rivetted connection. Rocker Roller bearings are provided to all spans.

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	30.5 m	Open Web Through	BA - 11461	31926	32460	5280	7723.7	55.00	2.080	32660	1620	1303
2	45.7 m	Open Web Through	BA - 11481	47240	47850	5280	7773.0	99.61	3.140	48050	1674	1343
3	61.0 m	Open Web Through	BA - 11581	63000	63700	5500	9615.0	176.00	4.000	63900	2183	1823
4	76.2 m	Open Web Through	BA-11601/R	78800	79600	5500	11185.0	260.56	5.500	79800	2248	1858

Table : 1.4 B Open web underslung girder welded type for MBG loading

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	61.0 m	Open Web Under Slug	BA - 11661	63000	63610	3500	7843.00	177.540	3.860	63810	1812	7826
2	45.7 m	Open Web Under Slug	BA - 11641	47244	47854	2600	5722.60	116.500	3.320	48054	1776	5775.6

Table : 1.5 A Open web (BG) welded type HM - loading

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	30.5 m	Open Web Through	BA-11521	31926	32460	5280	7706	63.00	2.30	32660	1549	1232
2	45.7 m	Open Web Through	BA-11501	47240	47850	5400	8224	116.47	4.00	48050	1603	1297
3	61.0 m	Open Web Through	BA-11551	63000	63700	5500	9702	222.93	5.79	63900	2082	1777
4	76.2 m	Open Web Through	BA-11621	78800	79600	5500	11206	323.40	9.28	79800	2248	1858

Table : 1.5 B Open web 25t loading (welded through type). All through spans members are connected by HSFG bolts except under slung members are having rivetted connection. Rocker Roller bearings are provided to all spans.

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	30.5 m	Open Web Through	B - 17161	31926	32460	5280	7678.4	72.478	2.246	32660	1627	1303
2	45.7 m	Open Web Through	B - 17181	47240	47850	5400	8237.5	135.896	4.016	48050	1718	1358
3	61.0 m	Open Web Through	B - 17021	63000	63700	5500	9794	222.360	5.790	63900	2183	1823
4	76.2 m	Open Web Through	B - 17041	78800	79600	5500	11244.4	321.362	9.280	79800	2336	1823
5	30.5 m	Open Web Under Slung	B - 17141	31900	32450	2300	5073	69.190	2.384	32650	1776	5157

Table : 1.5 C Open web DFC 32.5t axle load (welded through type). All through spans members are having rivetted connection. Rocker Roller bearings are provided to all spans.

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	30.5 m	Open Web Through	B - 17061	31926	32460	6300	10922.4	109.142	2.940	32660	1660	1313
2	45.7 m	Open Web Through	B - 17081	47240	47850	6400	11154.0	190.100	5.220	48050	1753	1358
3	61.0 m	Open Web Through	B - 17121	63000	63700	6450	11549.0	278.100	9.258	63900	2428	1898
4	76.2 m	Open Web Through	B - 17101	78800	79600	6500	11510.0	484.916	12.586	79800	2438	1898

Table : 1.6 A MBG Composite plate girder of welded type

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	9.15 m	Plate Girder	B - 1623	10000	10200	2200	666	8.1	0.44	10300	1928	1816
2	12.2 m	Plate Girder	B-1569/R	13100	13300	2200	1142	10.81	0.56	13400	2379	2292
3	18.3 m	Plate Girder	B-1534/R	19400	19650	2200	1478	23.35	0.704	19800	2667	2632
4	18.3 m	Plate Girder	B- 1759	19400	19650	2200	1373	26.6	0.70	19800	2553	2527
5	20.0m	Plate Girder	B-1581/R	21150	21450	2200	1680	26.20	0.70	21550	2965	2830
6	24.4m	Plate Girder	B-1730	25600	26050	2200	1967	42.87	1.05	26300	3200	3113

i)Drawing No.B - 1569 / R for Span 12.2m and B-1534 / R are suitable for 4^0 Curve.
ii)Drawing No.B-1759 for Span 18.3m is for Restricted depth for straight track.Remaining all spans are suitable for only Straight Track.
iii)For all above spans Sliding Bearings are provided but suitable Elastomeric Bearings can be used.
iv) All above spans are having Rivetted connection except for Span 18.3m having Drawing No.B-1759 are having HSFG bolt connection.
v)For all above spans Channel Shear Connectors are provided of Size 250 mm x 80 mm x 25 mm.

Table : 1.6 B 25t Composite plate girder of welded type (with stud as shear connectors and elastomeric bearings)

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	12.2 m	Plate Girder (Riveted)	B - 11752	12200	13300	2400	1150	11.89	1.05	13400	2470	2300
2	18.3 m	Plate Girder (Riveted)	B - 11753	19400	19650	2400	1637	25.88	1.295 1.512*	19800	2900	2791
3	24.4m	Plate Girder (HSFG Bolt)	B-11751R	25280	26050	2400	1956	48.61	2.54	26200	3222	3102

Table contd.

Table : 1.6 B continued from previous page

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
4	30.5m	Plate Girder (Riveted)	B-11754 R1	31900	32450	2400	2630	79.317	1.924	32600	3919	3805

i) Drg. No.B - 11752 for Span 12.2m is suitable upto 4o Curve. Weight of Bed Plate is 1.05 t but weight of Bearing is 1.05 t per span excluding Elastomeric Pad weight.

ii) Drg. No.B-11753 for Span 18.3m is suitable upto 2o Curve. Weight of Bed Plate is 1.512 t but weight of Bearing is 1.295 t per span excluding Elastomeric Pad weight.

iii) Drawing No.B - 11751 / R for Span 24.4m is suitable for New Fatique Criteria. Weight of Bearing is 2.54t but Total weight of Bearing in drawing is shown 1.950633t excluding Elastomeric Pad weight.

iv) Drawing No.B - 11754 for Span 30.5m is suitable upto 4^0 Curve. Weight of Bed Plate is 3.0272t but weight of Bearing is 2732.30 t excluding Elastomeric Pad weight.

Table : 1.6 C 32.5 t DFC Composite plate girder of welded type (riveted connection having elastomeric bearing)

All dimentions in mm.

SN	Normal clear span	Type of girder	Drawing number	Center of bearing of span	Overall length of span	Center of Girders	Depth at center	Weight of Span	Weight of Bear-ing	Center of Piers	Distance between R.L. to top of Abutment D_1	Distance between R.L. bottom of Girder at Center D_2
1	2	3	4	5	6	7	8	9	10	11	12	13
1	12.2 m	Plate Girder	B - 11764	13100	13300	2600	1224	12.509	1.170	13400	2579	2435
2	18.3 m	Plate Girder	B - 11763	19400	19650	2600	1626	27.134	1.483	19800		
3	24.4m	Plate Girder	B - 11761	25600	26050	2600	2171	51.212	1.883	26200		
4	30.5m	Plate Girder	B - 11762	31900	32450	2600	2656	85.457	3.073	32600		

i) All Drawings are suitable for Straight Track only. All spans are having Stud Shear Connectors.

■ ■ ■

CHAPTER 2

STEEL GIRDERS FOR RAILWAY BRIDGES

2.0 INTRODUCTION

Steel girder bridges form a vital but vulnerable link in a railway system. Damage to a bridge may take a long time for repairs and in that case financial repercussions will be quite severe on account of high cost of repairs and interruption to traffic. Most of steel girder bridges built and put in service prior to 1950 are of non-standard type and spans. Hence it is very essential to know the loading mechanism, structural behavior and defects likely to develop during service so as to take timely action by maintenance officials. Steel girders put in track prior to 1905 and steel rolled prior to 1895 are considered as early steel girders. There was no strict control on sulphur and phosphorous content during the steel manufacturing process at that time. These girders are prone to cracks/ fractures and sudden failure due to brittleness.

2.1 LOADS

For the purpose of computing stresses in steel girder of Track Bridge, during design, following loads are considered as stipulated in Bridge Rules.

2.1.1 Dead load

Consists of the portion of weight of superstructure and fixed load coming on them as self weight.

2.1.2 Live load

Railway track steel girder bridges are designed to one of the following loading standards.

2.1.2.1 Broad Gauge (1676 mm)

BGML (Broad Gauge Main Line) 1926- Prior to 1975 all steel girders on main line were designed for BGML standard which caters for maximum axle load of 22.9 t for locomotive with trailing load of 7.67 t/m. (BGBL was adopted for branch lines) Fig. 2.1 (a).

RBG (Revised Broad Gauge) 1975- The bridge loading was revised in 1975 (considering the new types of locomotives) and RBG loading was evolved which caters for a maximum axle load of 22.5 t (220.6 kN) for locomotives with trailing load of 7.67 t/m (75.2 kN/m) on track with the maximum axle load to 22.9 t (224 kN) for wagons Fig. 2.1 (b).

MBG (Modified Broad Gauge) 1987- With the anticipated growth in traffic by the turn of the century and consequent, use of heavier and more powerful locomotives, loading was modified during 1987 and MBG loading was evolved which caters for maximum axle load of 25 t (245 kN) for the locomotive with trailing load of 8.25 t/m (80.9 kN/m) on both sides of locomotives Fig. 2.1 (c).

HML (Heavy Mineral Loading) - The locomotives with a maximum axle load of 30.0 t (294.2 kN) and a train load of 12.0 t/m (117.7 kN/m) to be adopted for bridges on identified routes as and when approved by Railway Board Fig. 2.1 (d).

25 t Loading 2008 - With a maximum axle load of 245.2 kN (25.0 t) for the locomotives and a train load of 91.53 kN/m (9.33t/m) on both sides of the locomotives Fig. 2.1 (e).

DFC loading (32.5t axle load) - With a maximum axle load 0f 245.25 kN (25.0 t) for the locomotives and a train load of 118.99 kN/m (12.13 t/m) on both sides of the locomotives. The maximum axle load of wagons are 318.825 kN (32.5 t) Fig. 2.1 (f).

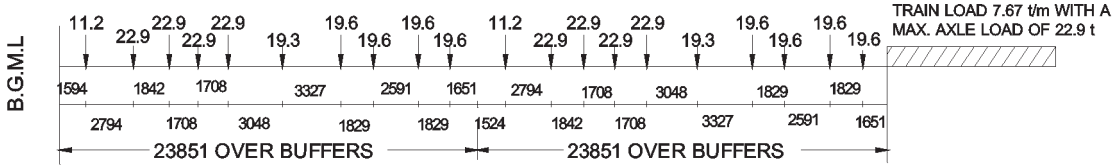


Fig. 2.1 (a) Loading standard BGML

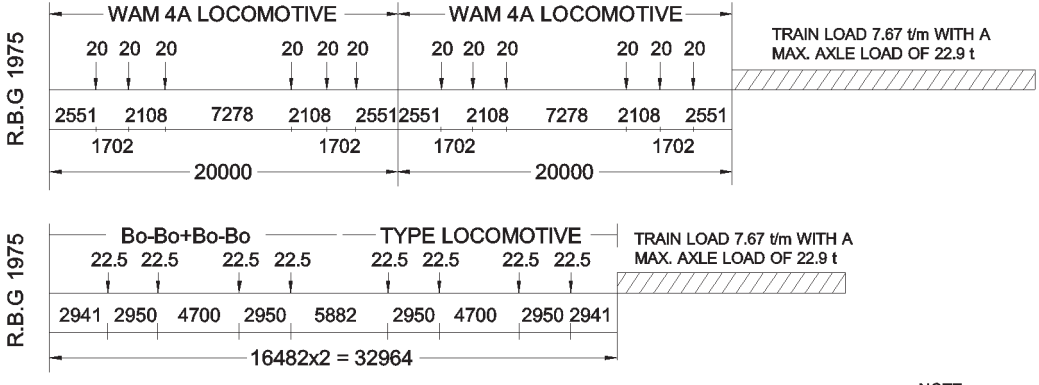


Fig. 2.1 (b) Loading standard RBG

NOTE:
AXLE LOADING IN TONNES
AXLE SPACING IN MILLIMETRES

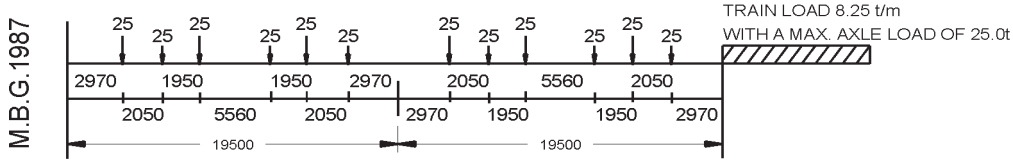
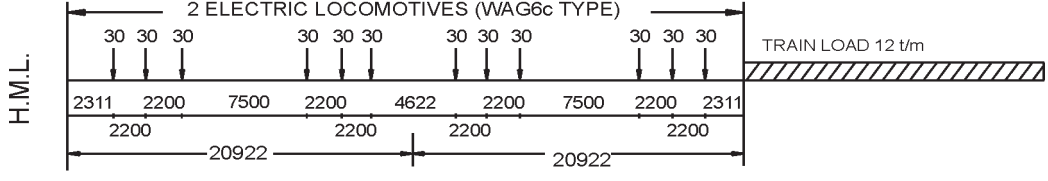


Fig. 2.1 (c) Loading standard MBG



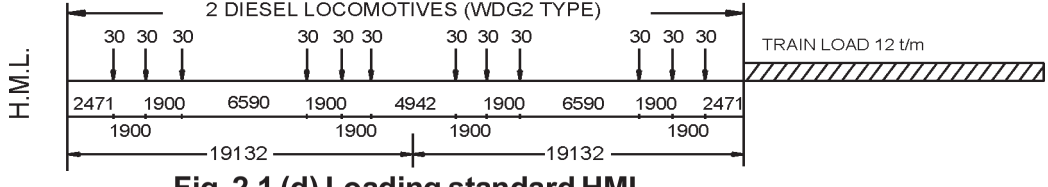
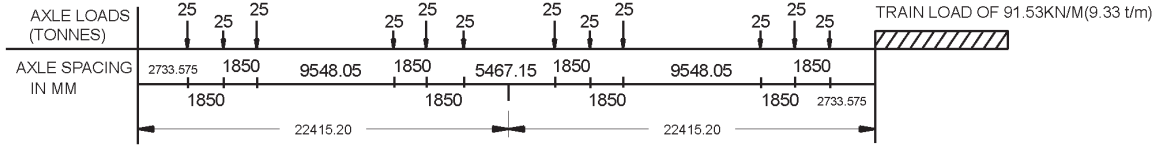


Fig. 2.1 (d) Loading standard HML

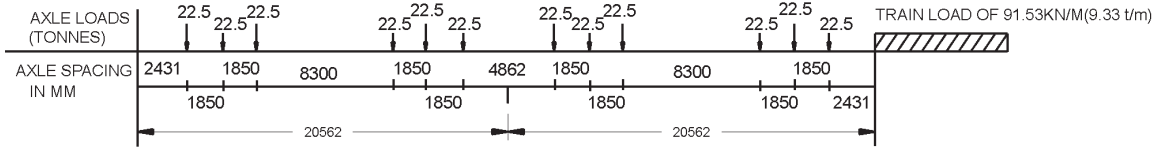
COMBINATION-1: Double headed diesel loco



LONGITUDINAL FORCES

TRACTIVE EFFORT PER LOCO.....63.T(618.03KN)
BREAKING FORCE PER LOCO AXLE...25% AXLE LOAD
BREAKING FORCE OF TRAIN LOAD ...13.4% 0F TRAIN LOAD

COMBINATION-2: Double headed electric loco(2 WAG9H)

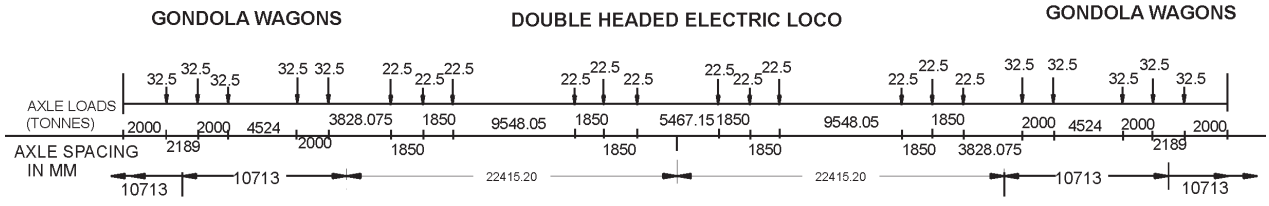


LONGITUDINAL FORCES

TRACTIVE EFFORT PER LOCO.....52.0T(510.12KN)
BREAKING FORCE PER LOCO AXLE...25% AXLE LOAD
BREAKING FORCE OF TRAIN LOAD ...13.4% 0F TRAIN LOAD

Fig. 2.1 (e) '25t Loading -2008'

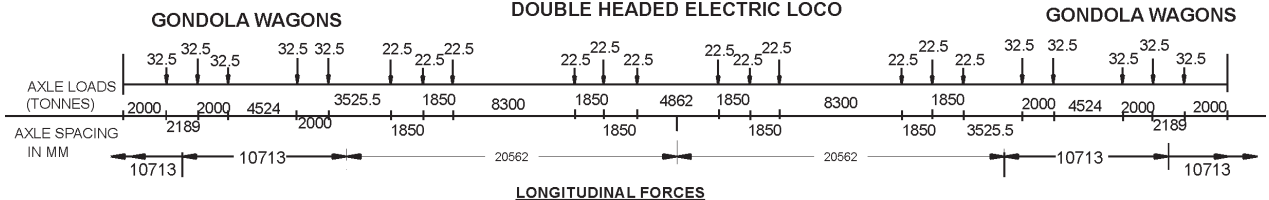
COMBINATION-1: Double headed electric loco



LONGITUDINAL FORCES

TRACTIVE EFFORT PER LOCO.....63.0T(618.03KN)
BREAKING FORCE PER LOCO AXLE...25% AXLE LOAD
BREAKING FORCE OF TRAIN LOAD ...13.4% 0F TRAIN LOAD

COMBINATION-2: Double headed electric loco (2 WAG9H)



LONGITUDINAL FORCES

TRACTIVE EFFORT PER LOCO.....52.0T(510.12KN)
BREAKING FORCE PER LOCO AXLE...25% AXLE LOAD
BREAKING FORCE OF TRAIN LOAD ...13.4% 0F TRAIN LOAD

Fig. 2.1 (f) 'DFC loading (32.5t Axle Load)'

2.1.2.2 Metre Gauge (1000 mm)

MGML 1929 - Maximum axle load of 13.2 t (129.4 kN) for locomotives with trailing load of 3.87 t/m (37.95 kN/m) following the locomotives.

2.1.2.3 Equivalent uniformly distributed loads (EUDL)

For simplicity of calculations, the Equivalent Uniformly Distributed Loads (EUDL) have been worked out for various spans upto 130 m and the same have been tabulated in Indian Railway Bridge Rules. The EUDL have been listed separately for arriving at the maximum bending moment and the shear for simply supported spans. For design of footpath or F.O.B., live load including impact is specified as 4.8 kN/m2 (490 kg/m2) of foot path area. Table 2.1 (a) shows comparative statement of BGML/ RBG / MBG / HM / 25 t / DFC loading with EUDLs and Table 2.1 (b) shows longitudinal forces for guidance.

2.1.3 Impact effect

In railway track bridges, this is defined as "Dynamic Augment". The Co-efficient of Dynamic Augment, CDA=0.15+ $\frac{8}{6+L}$ subject to maximum value of 1, where L is loaded length in metre. The CDA is further corrected by a factor $\frac{Vr}{V}$, where Vr is designed speed in kmph and V is 125 kmph for BG and 100 kmph for MG. The CDA shall never be taken less than 0.1. It is considered in addition to the live load being equivalent to the CDA

Table 2.1 (a)

Comparative statement of bending moment and shear for broad gague

Span (m)	BGML EUDLs (t)		RBG EUDLs (t)		MBG EUDLs (t)		HM EUDLs (t)		25 (t)		DFC EUDLs (t)	
	BM	Shear	BM	Shear	BM	Shear	BM	Shear	BM	Shear	BM	Shear
6.5	89.3	110.2	82.3	96.8	89.3	104.4	109.9	129.5	93.08	107.32	111.24	136.22
13.0	147.2	163.7	129.7	145.3	150.4	170.3	177.4	201.7	150.37	170.31	186.45	210.98
20.0	202.7	222.4	177.1	199.1	200.3	221.1	261.8	286.2	210.55	231.64	271.93	300.27
30.0	280.0	302.3	252.0	273.3	278.1	305.7	369.9	404.2	295.35	325.07	382.01	421.01
45.0	399.5	430.1	360.85	389.5	394.85	430.6	540.1	580.5	419.85	465.11	558.125	600.765
60.0	514.8	552.8	470.9	503.7	515.1	555.0	720.0	758.3	559.80	605.10	731.06	783.20
75.0	628.0	672.0	584.0	618.8	634.3	679.1	900.0	934.5	699.75	745.08	915.81	965.01
90.0	742.0	789.8	698.0	734.1	753.7	803.1	1080.0	1112.4	839.70	885.05	1098.16	1146.76
120.0	973.0	1025.3	926.7	964.4	1001.4	1050.9	1440.0	1470.6	1119.60	1164.97	1459.26	1510.87

multiplied by live load which gives maximum force (bending and shear) in the member under consideration for speed upto 160 kmph on BG and 100 kmph on MG.

2.1.4 Forces due to curvature and eccentricity of track

Where a track (or tracks) on bridge is curved, allowance for centrifugal action of moving load as well as effect of eccentricity of track (curved) over girders (straight) shall be included in designing a member, all tracks on the structure being considered as fully occupied.

2.1.5 Temperature effect

When any portion of the structure is not free to expand or contract under variation of temperature, allowance shall be made for the stresses resulting from this condition.

2.1.6 Frictional resistance of expansion bearings

Where the frictional resistance of expansion bearings has to be taken into account, the co-efficient shall be assumed as per type of bearings provided. The value of the co-efficients can be taken as given in Clause 2.7.1 of Bridge Rules.

2.1.7 Longitudinal force

Where a structure carries railway track, provision shall be made for longitudinal loads arising from anyone or more of the following:

The tractive effort of driving wheels of locomotives depending on traction characteristics of locomotive.

The braking force resulting from the application of brakes to all braked wheels with 13.46% of wagon axle load for air brake and 10% of axle load for vacuum brake stock.

Resistance to the movement of the bearings due to change of temperature.

Table. 2.1 (b) Comparative statement of longitudinal forces

Span (m)	Longitudinal Forces (t)					
	BGML	RBG	MBG	HM	25 (t)	DFC
6.5	25.6	22.5	33.3	33.3	33.32	33.32
13.0	35.5	37.5	50.0	60.0	63.00	63.00
20.0	41.6	50.0	75.0	75.0	74.97	74.97
30.0	47.6	65.0	100.0	100.0	99.96	99.96
45.0	56.3	75.45	100.0	120.0	126.00	126.00
60.0	64.4	96.2	101.5	135.0	126.00	126.00
75.0	71.2	119.1	118.1	135.0	126.00	141.54
90.0	77.2	146.6	134.7	147.1	142.50	163.86
120.0	88.5	187.8	167.8	195.4	180.00	215.57

2.1.8 Racking force

Lateral bracings of the loaded deck of the railway track steel girder shall be designed to resist racking force (force caused by nosing and swinging effect of moving load over the rails), in addition to the wind and centrifugal force.

2.1.9 Wind pressure effect

This is caused by the wind on the girder as well as on the body of moving stock and is a transverse load.

2.1.10 Forces and effects due to earthquake

Earthquake shocks cause movement of ground on which the structure is situated. This ground movement causes vibration of structure. The seismic forces need not be considered for Railway Bridge located in Zones upto III for bridges of overall length less than 60 m or span less than 15 m, for Zone IV and V seismic forces will be considered irrespective of span of bridges (Zones indicated in IS: 1893).

2.1.11 Erection stresses

Allowance shall be made in design for stresses set up in any member during erection. Such stresses may be of different nature from those which the member will be subjected to during actual service (tension instead of compression or vice-versa). These depend on launching scheme. Hence temporary strengthening has to be made if required for the scheme adopted.

2.1.12 Loads for road bridges (ROB)

Road Bridges shall be designed to following loading standard. Accordingly they are designed to carry anyone of the loading, namely:

IRC Class "AA" Loading
IRC Class "A" Loading
IRC Class "B" Loading

2.2 CODES AND SPECIFICATIONS

Steel girders (superstructure) are designed, fabricated, erected and maintained in accordance with following

codes and specifications.

IRS - Steel Bridge Code - 2003 for design of steel and wrought iron bridges carrying rail, road and pedestrian traffic (mostly riveted girder)

IRS - Welded Bridge Code 2001 for metal arc welding in mild steel bridges carrying rail, rail cum road or pedestrian traffic (for welded girder only). This code incorporates submerged arc welding.

IRS - Specification B1-2008 for fabrication, erection and maintenance of steel girders and turn-tables.

2.2.1 Steel

As stipulated in Clause 8 of IRS B1 - 2008 structural steel used for steel girders and steel structure in Indian Railways as follows:

2.2.1.1 IS-2062 Grade 'A' as rolled semi killed or killed shall be used for foot over bridges and other structures (whether riveted / welded fabrication) subjected to non-critical loading and not subjected to impact loading.

2.2.1.2 IS - 2062 Grade 'B0' fully killed and normalized/ control cooled where service temperature does not fall below 0^0 C shall be used for welded/riveted girders subjected to railway loading. For this grade of steel impact test at 0^0 C is mandatory. Plates less than 12mm thick need not be normalized / controlled - cooled. (Note: Steel girders of track bridges up to 76.2m spans are fabricated with this steel).

2.2.1.3 IS-2062 Grade 'C' fully killed and normalized/ control cooled ensuring impact properties at (-) 20^0C shall be used for sub zero temperature areas for welded/ riveted girders subjected to railway loading.

Note: Rolled section like angles, channels, I - section etc. confirming to IS-2062 Grade 'A' or 'BR' may be used in structure of riveted girder subjected to railway loading till such time rolled sections confirming to IS-2062 grade 'B0' are not available in market. For grade 'BR' steel impact test is optional at room temperature. Provision of high strength steel to E - 450 of 'BR' quality may not be used for riveted girder.

Supply of steel - General requirement relating a supply of structural steel shall confirm to IS 8910. All finished steel shall be well and cleanly rolled to the dimensions, sections and masses specified. The finished material shall be reasonably free from surface flaws; rough / jagged and imperfect edges and all other harmful defects. Minor surface defects may be removed by the manufacturer / supplier by grinding provided the thickness is not reduced locally by more than 4 percent but not exceeding 7 percent may be made subject to mutual agreement between the purchaser and the manufacturer / supplier. Grades of steel given in Table 1 and 2 of IS: 2062 are reproduced here. For grades E 250 to E 410, there shall be four sub-qualities A, BR, B0 and C. While placing the order, the steel should be designated by "Grade Designation" and "quality" (See Table 2.2 and Table 2.3).

2.2.1.4 High tensile steel shall comply in all respect with the requirement of IS-8500 (equivalent of old IS- 961) presently used for spans 91.5m and 122.2 m span (riveted truss).

2.2.1.5 Steel for rivets shall comply with the requirement of IS:1148 for hot rolled rivet bars for structural steel confirming to 2062 Grade Band IS: 1149 for high tensile steel girder.

Table 2.2 Chemical Composition
(Clauses 5, 8.1 and 8.2) of IS : 2062

Grade Design-ation	Quality	Ladle Analysis, Percent, Max					Carbon Equiv-alent (CE), Max	Mode of Deoxi-dation
		C	Mn	S	P	Si		
1	2	3	4	5	6	7	8	9
E 250	A	0.23	1.50	0.045	0.045	0.40	0.42	Semi Killed /Killed
	BR B0	0.22	1.50	0.045	0.045	0.40	0.41	Semi Killed /Killed
	C	0.20	1.50	0.040	0.040	0.40	0.39	Killed
E 275	A	0.23	1.50	0.045	0.045	0.40	0.43	Semi Killed /Killed
	BR B0	0.22	1.50	0.045	0.045	0.40	0.42	Semi Killed /Killed
	C	0.20	1.50	0.040	0.040	0.40	0.41	Killed
E 300	A BR B0	0.20	1.50	0.045	0.045	0.45	0.44	Semi Killed /Killed
	C	0.20	1.50	0.040	0.040	0.45	0.44	Killed
E 350	A BR B0	0.20	1.55	0.045	0.045	0.45	0.47	Semi Killed /Killed
	C	0.20	1.55	0.040	0.040	0.45	0.45	Killed
E 410	A BR B0	0.20	1.60	0.045	0.045	0.45	0.50	Semi Killed /Killed
	C	0.20	1.60	0.040	0.040	0.45	0.50	Killed

NOTES:

1. New grade designation system based on minimum yield stress has been adopted.
2. For semi-killed steel, silicon shall be less than 0.10 percent. For killed steel, when the steel is killed by aluminum alone, the total aluminum content shall not be less than 0.02 percent. When the steel is killed by silicon alone, the silicon contact shall not be less than 0.10 percent. When the steel is silicon-aluminum killed, the silicon content shall not be less than 0.03 percent and total aluminum content shall not be less than 0.01 percent.

3 Steels of qualities A, BR, B0 and C are generally suitable for welding processes. The weldability increases from quality A to C for grade designation E 250 and E 275.

4 Carbon equivalent (CE) would be calculated based on Ladle analysis only,

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

C	Carbon (%)
Mn	Manganese (%)
Cr	Cromium (%)
Mo	Molybdenum (%)
V	Vanadium (%)
Ni	Nickle (%)
Cu	Copper (%)

Table 2.3 Mechanical Properties
(Clauses 5, 10.3, 10.3.1, 11.3.1, 12.2 and 12.4)

Grade Design-ation	Quality	Tensile Strength R_m, (Min MPa[1]) (see Note 1)	Yield Stress R_{eH}, (Min MPa[1])			Percentage Elongation A1 Min at Gauge Length, $L_0 = 5.65$	Internal Bend Diameter Min (See Note 2)		Charpy Impact Test (See Note 3)	
			< 20	20-40	> 40		≤ 25	> 25	Temp ^{0}C	Min J
1	2	3	4	5	6	7	8	9	10	11
E 250	A	410	250	240	230	23	2t	3t	---	---
	BR								RT	27
	B0								0	27
	C								(-)20	27
E 275	A	430	275	265	255	22	2t	3t	---	---
	BR								RT	27
	B0								0	27
	C								(-)20	27

Table contd....

Table : 2.3 continued from previous page

1	2	3	4	5	6	7	8	9	10	11
E 300	A	440	300	290	280	22	2t	RT / 0	---	---
	BR								27	
	B0								27	
	C								(-)20	27
E 350	A	490	350	330	320	22	2t	---	---	---
	BR								RT	27
	B0								0	27
	C								(-)20	27
E 410	A	540	410	390	380	20	2t	---	---	---
	BR								RT	25
	B0								0	25
	C								(-)20	25

Notes:

1. In case of product of thickness / diameter more than 100 mm, lower minimum limit of tensile srength may be mutually agreed to between the purchaser and the manufacturer/supplier.
2. Bend test not required for thickness > 25 mm for grades E 300 to E 650. 't' is the thickness of the test piece.
3. For sub-quality BR, impact test is optional, if required, at room temperature (25 ± 2^0 C).

[1)]IMPa = IN/mm^2 = IMN/m^2 = 0.102 kgf/mm^2 = 144.4 psi.

2.3 TYPES OF STEEL GIRDERS FOR TRACK BRIDGE

RDSO, Lucknow has designed and issued fabrication drawings for standard spans of following types:

a) Beam type (solid web plate girders) for spans 9.15, 12.2, 18.3, 24.4 and 30.5 m as open deck and composite girders. The present policy of Railway Board is to use RCC / PSC slabs for spans upto 6.1 m and adoption of RCC / PSC girders for spans upto 24.4 m wherever possible.

b) Truss type (Open web girder) for spans 30.5, 45.7, 61 and 76.2 m.

c) Special Type: Rail cum road bridges for spans of 91.5 and 122.2 m but these bridges are very limited in number.

Table 1.1 A to 1.6 C indicates list of steel girders with important dimensions and weights of spans. All standard track bridge steel girders (superstructure) are simply supported structures and hence maximum bending stresses are in the centre of span and maximum shear stress is at ends. Bending stresses are resisted by flanges or chords. Top flange or chord resists compression. Bottom flange or chord resists tension. Shear stresses are resisted by web plate or web members of open web girder.

2.3.1 Solid web plate girder-deck type

As a thumb rule depth to span ratio of these girders is 1/ 10. Maximum size of beam (RSJ) rolled in Indian rolling mills is 600 x 210 mm. Earlier spans upto 6.1 m were

directly made with rolled RSJs or RSJs with top and bottom flange plates or duplicate RSJs. Details of such girder is shown in Fig.2.2. Spans 9.15 m and above are made with web plate and flange plates to form built up beam or I-section. Plate girders are further grouped according to the type of construction of beam or I-section as under;

a) Riveted plate girder (Open deck)
b) Welded plate girder (Open deck)
c) Welded composite girder (Ballasted deck)

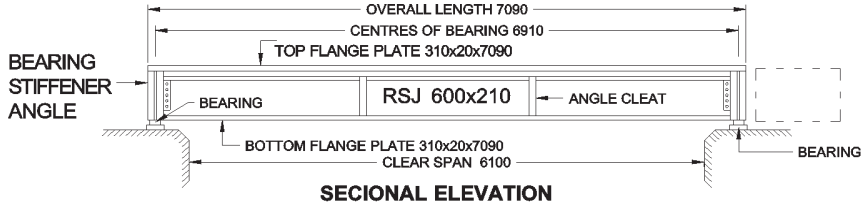
All built up plate girders (solid web) upto spans 35 m (115') need not be cambered as per Steel Bridge Code Clause 4.16.1. Because all standard plate girder spans are less than 35 m; therefore, the question of camber does not arise.

Standard plate girders are used as deck type where sleepers are resting on top flanges.

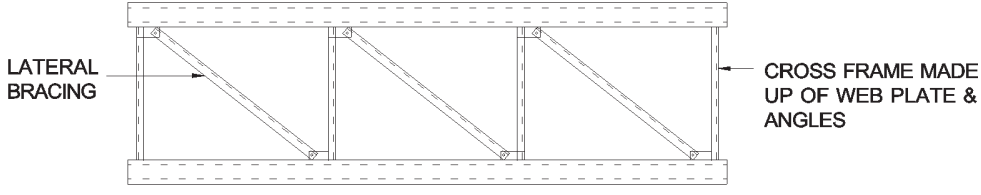
2.3.1.1 Riveted plate girder-deck type

On date 98% of steel plate girder bridges are of riveted constructions for spans 9.15, 12.2, 18.3, 24.4 and 30.5 m. Plate girders of 30.5 m are very few owing to fabrication problem and also being uneconomical. Following are the components of riveted plate girder:

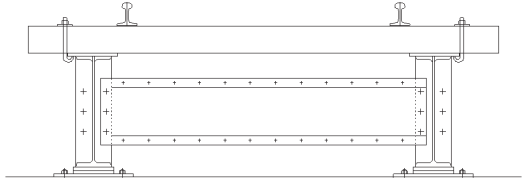
a) Built-up I-Section (including stiffeners)
b) Cross frames
c) Top lateral bracings
d) Bottom lateral bracings (provided for spans 24.4 m and above)
e) Bearings.



SECIONAL ELEVATION



PLAN



CROSS SECTION

NOTE:
ALL DIMENSIONS ARE IN MILLMETRES.

Fig.2.2 RBG riveted 6.1 m span.

Main component (Built-up I - section) - Top flange (compression member) is made up of flange angles, flange plates and web plate (portion between flange angles). Top flange resists bending compression stresses and gross area is considered as a cross section. Flange angles are essentially required to connect web and flange for riveted construction. To cater for higher bending stress in middle portion of span, additional flange plates are provided over first top flange plate which is provided throughout the length of span for sleeper seating.

Bottom flange (tension member) construction is similar to top flange. Bottom flange resists bending tensile stresses and net area is considered for a cross section. Greater cross section is required in the middle portion of the span which is provided with additional flange plates.

Web is made up with 3/8" or 10 mm thick plate for full length and depth of beam section. Web plate is stiffened against buckling with stiffener angles. Web resists shear stress which is maximum at the end of beam, hence closer pitches of rivets and closer interval between two intermediate stiffeners than in middle portion are provided. The load on the entire span is transferred through bearings to bed block and in turn to substructure. Hence bearings stiffeners are provided with 2 angles back to back on either side of web plate over the bearing. Bearing stiffeners are straight and outstanding leg is snug fitting between top and bottom flange. Packing plate is provided between web and stiffener connecting leg equal to flange angle thickness. Intermediate stiffeners are single angle on either side of web and outstanding leg is snug fitting between top and bottom flanges. Intermediate stiffeners are either straight with packing plate or joggled without packing plates. Outstanding leg of stiffener acts like a strut between top

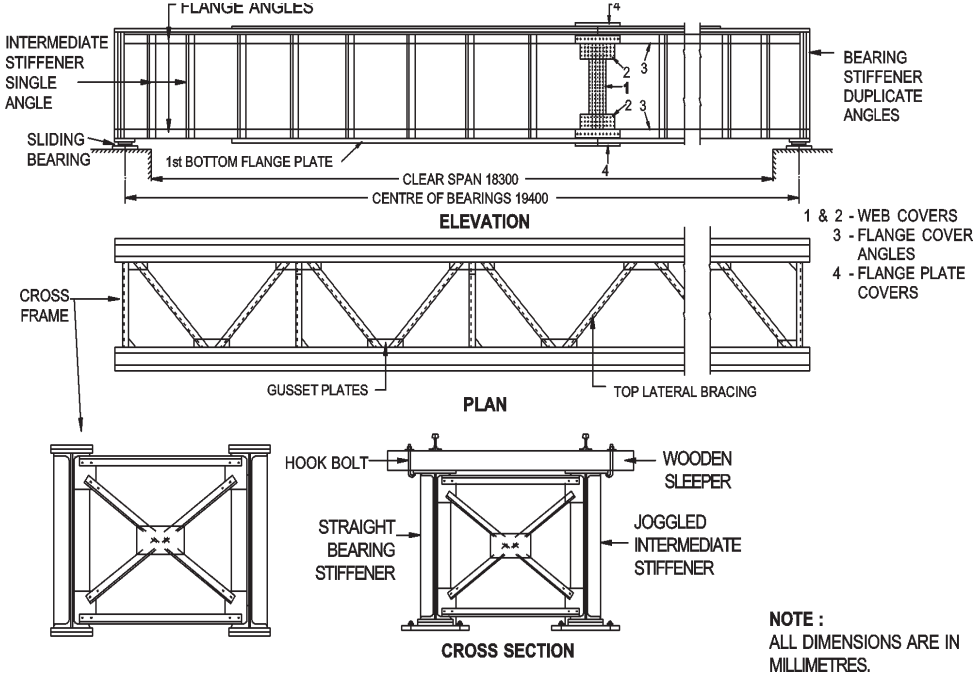


Fig. 2.3 RBG Standard 18.3 m span (riveted)

and bottom flange to resist web buckling caused by cross bending of sleeper and top flange.

Secondary Members- Cross frame consists of angle section for horizontal and diagonal members connected with gussets to stiffener legs for lateral rigidity. Top lateral bracings consist of angles connecting diagonally (in horizontal plane) to top flanges to reduce the unsupported length of compression flange to resist buckling. Bottom lateral bracings consist of angle connected to bottom flange for spans 24.4 m and above. All these cross frames, top lateral and bottom lateral bracings are for lateral rigidity and are secondary members.

Centralised articulated (sliding type) bearings are provided with steel base plates which are anchored to bed blocks with anchor bolts.

Wooden channel sleepers with pad plates are provided on top flanges to support track and anchored with hook bolts. Notches are required on bottom face of wooden sleeper to accommodate rivet heads; hence this poses a problem for frequent painting of sleeper seats which are more prone to corrosion due to steel in contact with wood/ steel and abrasion of sleepers.

Riveted deck type plate girders are strong and sturdy, and simple for fabrication and launching. All standard spans are generally fabricated in engineering workshop of each zonal railway and transported to site for launching. To facilitate transportation from workshop to site of bridge spans 9.15 m and 12.2 m are fabricated as complete span. 18.3 m span is provided with one joint in I-section, i.e. four numbers of I-sections are fabricated for one span, 24.4 m and 30.5 m spans are provided with two joints in

I - section, so that six numbers of I -sections are fabricated for one span. The maximum 13.5 m long component can be loaded in a BFR. Therefore, splice material such as cover flange plates, cover flange angles, cover web plates are required to be assembled with the ' I ' section to form span at site with field rivets for spans 18.3 m and above. Fig. 2.3 indicates the details of a riveted girder.

NOTE : Semi through non-standard plate girders are similar to deck type (mentioned above) except that the sleepers are resting on floor system consisting of stringer and cross girders but no bracings are provided to top flanges of girder.

2.3.1.2 Welded plate girder-deck type

On Indian Railways, majority of steel girders are of plate girder type. Till 1980, these plate girders were fabricated as riveted girders. The riveted construction tends to make the structure heavy and costly, besides posing maintenance problems due to rivet heads on top flange plates which leads to heavy corrosion. During 1980-82, with proven welding technology for fabrication of dynamic structures and availability of indigenous automatic welding equipments and consumables for sound welding, the fabrication of welded girders has been taken up for railway track bridges. RDSO, Lucknow has issued standard welded plate girder drawings for spans of 12.2, 18.3 and 24.4 m for BG and 6.1, 9.2, 12.2, 18.3, 24.4 and 30.5 m for MG.

Advantage of welded girder

a) Welded girder with riveted intermediate stiffeners result in saving of steel upto 25%.

b) Welded girder eliminates the need of rolled sections of non-standard sizes and shapes. Also due to non-availability of particular rolled section using higher section leading to uneconomical construction is avoided.

c) Eliminates drilling of holes and hence gross area becomes net area for tension members (Bottom Flange).

d) Welded girder eliminates cumbersome connections and water pockets.

e) Welded girder requires less maintenance due to elimination of rivet heads on top flange thereby facilitating the painting of sleeper seats frequently thus reducing maintenance and repairs cost.

f) Aesthetic superiority and higher production rates with lesser input are added advantages.

Components of welded girder

Following are the components (similar to riveted girder)

a) Welded I-sections (including welded or riveted intermediate stiffeners)

Main components are welded I-sections which are similar to riveted plate girders except the following:

i) Web and flange connection is provided with continuous fillet weld (instead of flange angles with riveted connections)

ii) Earlier stiffeners were made up of plates instead of angle sections and are welded with fillet weld to the web but now revised drawings are followed for welded girders with revitted angle stiffeners for intermediate stiffeners.

b) Cross frames

c) Top lateral bracings

d) Bottom lateral bracings for spans 24.4 m and above

e) Bearings

f) Top flange plate is made with one flange plate and requires increase in cross section in middle portion of span, which is met with by increasing the width of flange plate to cater for bending (compression) stresses. Sometimes due to non-availability of full length of flange plates, "Butt" welding is provided with double "V" groove. Full penetration weld on both sides of plate is provided at junction to increase in width of flange plate.

g) Bottom flange plate is made with one flange plate similar to top flange but it is a tension member.

   To avoid stress concentration resulting in crack initiation during service, at the junction of different widths of top and bottom flange plates, (at butt weld) 1:5 side slope is provided. Butt weld in flange plates should be avoided by arranging longer plates for economical fabrication and maintenance during service life, if possible.

h) Web plate is made with 10 mm thick plate for full length and depth of girder. Sometimes due to non-availability of full length of plate, square butt weld on both sides of web plate is provided. Web plate is stiffened with plate stiffeners. Bearing stiffeners consist of 2 numbers plate stiffeners on either side of web over the bearings, and is welded with continuous fillet welding to web, top and bottom flanges. Intermediate stiffeners are also provided

with plate stiffeners on either side of web plate at staggered locations to avoid cruciform welding. Welded bridge code clause No. 5.3.2.1 stipulates that filet welds at right angles to the line of principal stress in plate subjected to tension shall be avoided in dynamically loaded structures, hence intermediate stiffeners are welded to web plate and top flange plate with continuous fillet weld and stiffener is terminated 50 mm short of bottom flange fillet weld (tension flange). This type of detailing leads to classification of welded girder in detail category '70' shown in "Table 9.1 of Appendix 'G' of Steel Bridge Code" for fatigue consideration reducing permissible stress to a very low value resulting in increased cross section of structure. To achieve economical welded girders these are provided with riveted intermediate stiffener (angles section with riveted connections) which classify welded girders in detail category "90" of same table for fatigue consideration with higher permissible stress.

RDSO, Lucknow has issued welded girder drawings with (i) Welded intermediate stiffener, and (ii) Riveted intermediate stiffener. Presently welded girders are fabricated with riveted intermediate angle stiffener.

In welded girders, connections made during fabrication in workshop are only welded. Remaining all connections are done at site, such as cross frames, top lateral bracings and splice material for 18.3 m span and above are provided with riveted connections only. Field welding is not permitted for fabrication of welded girders of track bridge without prior approval of competent authority.

Cross frames, top and bottom lateral bracings are similar to riveted girder with riveted connection for site joints. Centralised articulated bearings (sliding type) are provided to welded girders similar to riveted girders.

Welded connections are strong enough to resist the static loads but are prone to failure under dynamic loading due to fluctuation of stresses causing crack initiation. Welded plate girder of track bridge therefore requires careful design and detailing. Fatigue strength of welded structure depends upon the construction details.

In general, welded girders are provided with following welded joints:

1) Butt Weld:
   a) double "V" groove - For top & bottom flange
   b) square - For web plates
2) Fillet Weld:
   a) "T" fillet (continuous) - For top & bottom flange connections to web plate
   b) Side fillet (continuous) - All stiffeners and bearings.

All fillet butt welds for the fabrication of welded –I section, are required to be made by submerged arc welding process, either fully automatic or semi automatic type. Fig. 2.4 shows details of welded joints with weld parameters used for welded girder. Butt welds provided in top and bottom flange plates and web plates are to resist the same stress as parent metal and hence these welds are to be tested radiographicaily during fabrication. Welded Bridge Code clause No. 5.2 & 5.3 stipulates that "all butt

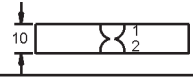
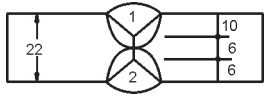
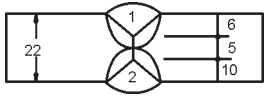
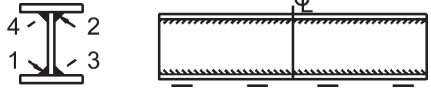
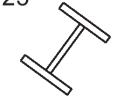
SR. No	JOINT FIT UP	WELD PARAMETERS					POSITION
		Step	Voltage (volt.)	Current (amp.)	carr.speed (m/min)	Wire Feed (m/min)	
1	BUTT WELD TOP FLANGE 	1 St.	32	550	0.4	1.25	FLAT DOWN HAND
		2 nd.	32	600	0.4	1.25	
2	BUTT WELD BOTTOM FLANGE 	RUN 1 St. 10 mm SIDE	32	650	0.5	1.50	do
		RUN 2 nd. 6mm SIDE	32	650	0.5	1.50	do
3	BUTT WELD TOP FLANGE 	RUN 1St. 10 mm SIDE	30	650	0.5	1.50	do
		RUN 2 nd. 6mm SIDE	32	700	0.5	1.50	do
4	FILLET SIZE 8mm. ONE PASS 		30	550	0.3	1.25	

Fig. 2.4 Details of welded joints

welds in dynamic structure are examined radiographicaily or by any other equally effective method". Fillet welds connecting top and bottom flanges to web, resist shear stress (resultant of horizontal and vertical shear) and hence full penetration continuous fillet weld is required. The entire length of fillet welds is checked by NDT methods and all the butt welds in flanges and web are required to be radiographed and cleared.

Steel used for welded plate girders for built up I-section with welded connections should conform to IS: 2062 Grade 'B0' fully killed, normalised and duly tested. Steel used for members like intermediate stiffeners cross-frames, lateral bracings, splice material with riveted connections should conform to IS: 2062 Grade 'A' and rivet steel to IS: 1148.

Fig. 2.5 and **2.6** show the details of welded plate girders (with welded intermediate stiffeners and riveted intermediate stiffeners).

Note: Site welding is generally prohibited. However, in certain unavoidable cases such as repairs maintenance work for girders in service it can be permitted by Chief Bridge Engineer / officer equivalent to the rank of SAG officer and above. During construction, it can be permitted on case to case basis by an officer equivalent to the rank of Chief Administrative Officer / Construction and is confined to connections having low stresses, secondary members, bracings etc. The suitability of parent metal to take welding, should, however, be tested first.

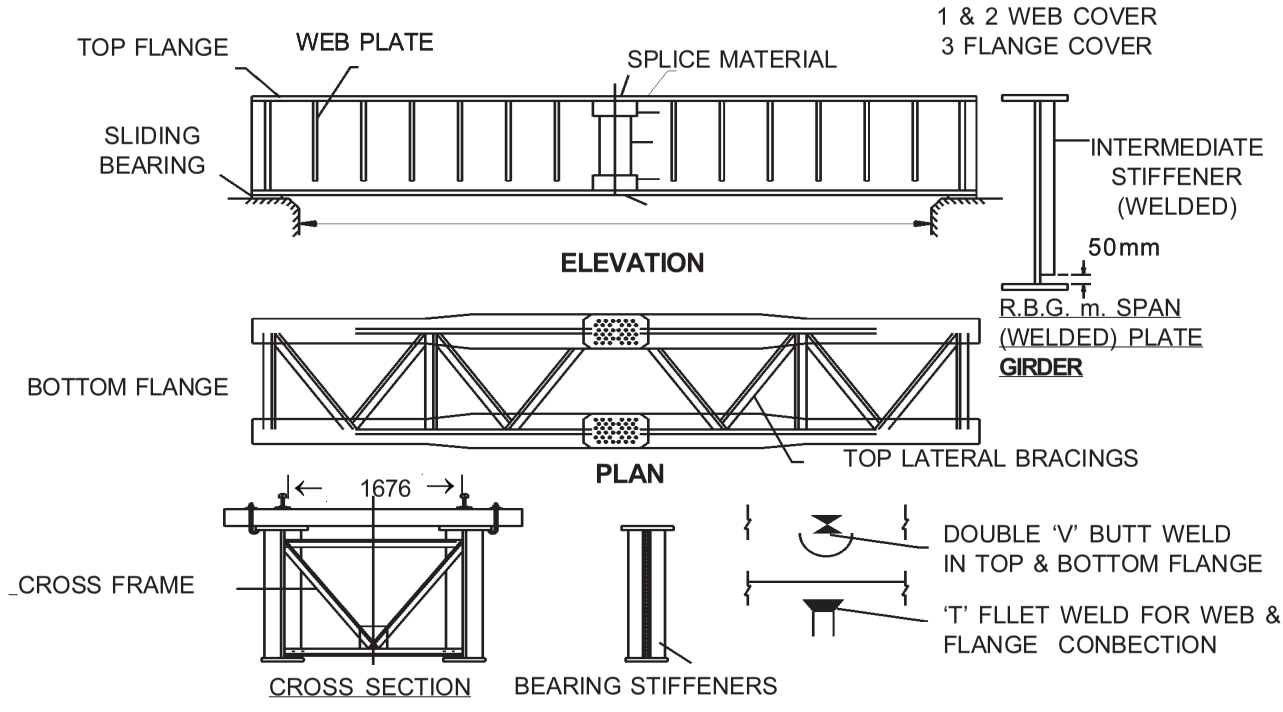


Fig. 2.5 RBG Standard 24.4 m Span (welded) plate girder

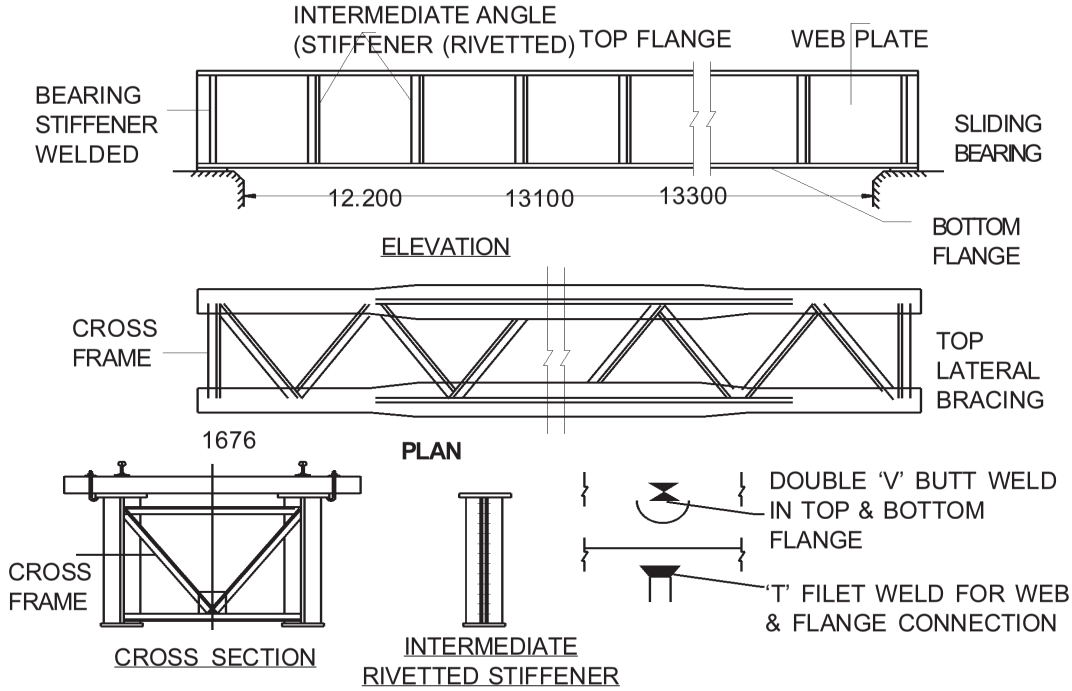


Fig. 2.6 MBG Standard (welded) 12.2 m plate girder with riveted bracing & intermediate angle stiffener

2.3.1.3 Composite girder of RCC slab and steel girder

For high speed trains and increased volume of traffic, strong track structure with concrete sleepers is essential for economical maintenance. Such track structure on bridges is possible with ballasted deck provided on composite girders.

Following are the advantages of composite girders:

a) Ballasted deck with PSC sleepers provides similar track structure on bridge as on the approach which results in better maintainability and greater riding comfort.

b) Superelevation for curved track can be provided with greater ease, being ballasted deck.

c) Machines can be deployed for maintenance of track or bridges.

d) Use of other type of sleepers, become possible as wooden sleepers is a scarce commodity now on Indian Railways,

e) Concrete is rich in compressive strength and steel is rich in tensile strength. Composite girder consisting of RCC deck with steel beams would be generally economical for spans ranging from 9.15 to 24.4 m. However, the actual choice depends on site conditions.

f) Less maintenance cost due to slab deck being of RCC. RDSO, Lucknow has designed and issued composite girder drawings for use on zonal railways for spans 9.15, 12.2, 18.3, 20 and 24.4 m for BG and 12.2 m for MG with welded construction.

Composite girders consist of the following components:

a) RCC deck (Cast in situ at the site of bridge) with shear connectors embedded in the slab.

   (Presently channel shear connectors are used and depending on availability of stud welding gun, use of stud shear connectors can be adopted)

b) Steel beams with shear connectors welded on top flange (Fabricated in workshop).

c) Cross frames

d) Bearings

Details:

a) The RCC deck is cast in situ after launching steel girders on substructure. Shear connectors such as stud bolts or channel section are provided on top flange plates of steel beams and welded all round with side fillet welds. Shear connectors are required to make cast in situ RCC slab and steel girder act together under load. Drawings are available for channel shear connectors as well as stud shear connectors.

b) This is similar to welded plate girder except that the height of girder is less and top flange plate is provided with only 10 mm plate and shear connectors. Bottom flange plates consist of two plates with continuous side fillet weld to resist tensile stress. Bearing stiffeners and intermediate stiffeners are the same as welded plate girders.

c) Cross frames consist of angles with riveted connections as well as splice material for spans 18.3 m and above are provided with riveted connection.

d) Bearings provided are sliding type bronze bearings. One end of the span is provided as free end in which steel bearing plate slides on bronze plate and the other end of span is provided with bearing plate resting on steel plate. Bearing on steel plate provides movement only during creep and shrinkage of concrete deck. Otherwise it acts like a fixed end.

Composite girders are designed as unpropped girders. In railway track bridges, propping of girder till whole concrete is set and acts monolithically with steel beam is not possible due to height of substructure and bed conditions. Composite girders are mostly used in new constructions and doublings. Its use poses problems during regirdering on account of the requirement of existing substructure jacketing due to increased dead weight and difference in height, as distance between rail level and bed block is more than that of the existing steel girder of same span.

In case of composite girders, the top flange plate with shear connectors (welded in staggered arrangement), should be made first, before the I-Section is made. Suitable jigs and fixtures are needed for fabricating the members by welding, to reduce the extent of warping and distortion.

Steel used for fabrication of composite girder of I-section should conform to IS: 2062 Grade "B0" fully killed and normalised. In the earlier design channel sections were used for shear connectors, but this being rigid connection causing cracks in concrete slab. Also the channels require large area to be welded with top flange plate of I-girder causing warping of top flange. To avoid these problems now a days welded stud bolts are used. They are very

flexible and create less heat affected area while welded to top flange plate of I-girder.Cross frame and splice material are of steel confirming to IS: 2062 Grade 'A' with riveted connections. Fig. 2.7 (a & b) shows the details of a welded composite girder.

Note: Site welding is generally prohibited. However, in certain unavoidable cases such as repairs maintenance work for girders in service it can be permitted by Chief Bridge Engineer / officer equivalent to the rank of SAG officer and above. During construction, it can be permitted on case to case basis by an officer equivalent to the rank of Chief Administrative Officer / Construction and is confined to connections having low stresses, secondary members, bracings etc. The suitability of parent metal to take welding, should, however, be tested first.

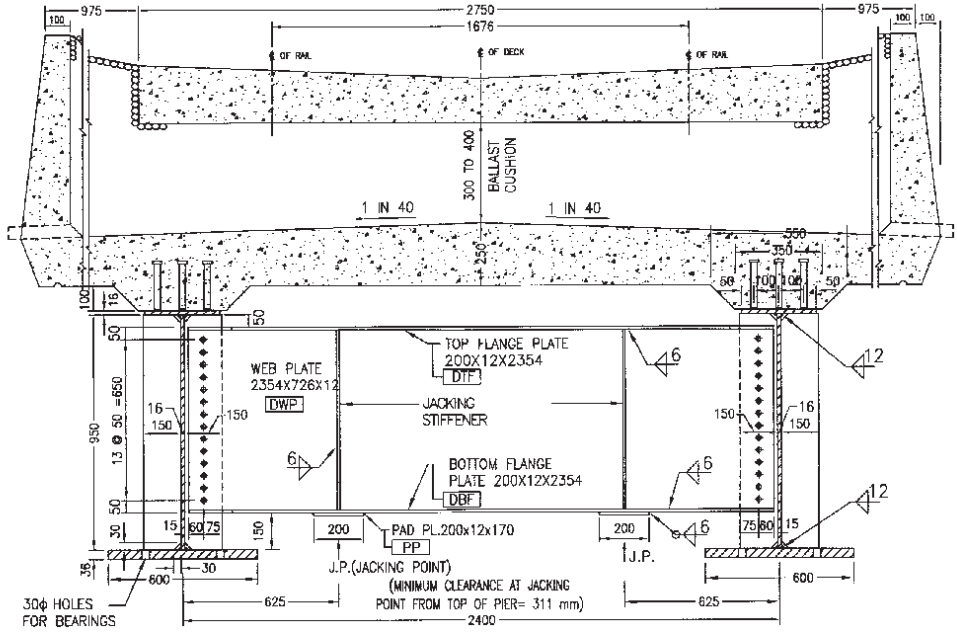


Fig. 2.7 (a) Cross section of welded types composite girder for 30.5 m span (RDSO / B - 11754/3R1)

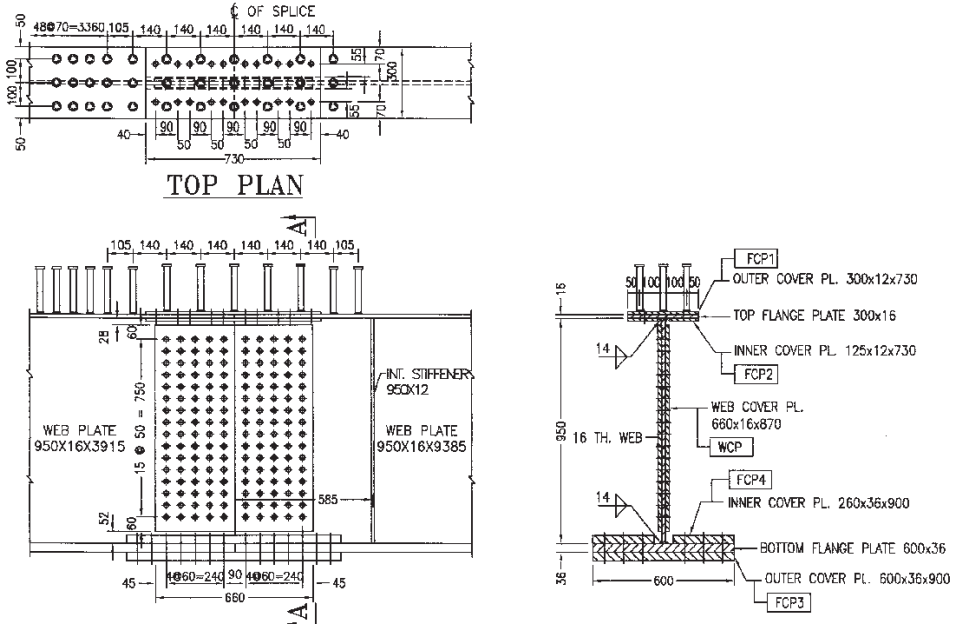


Fig. 2.7 (b) Welded types composite girder for 30.5 m span -details of splice (RDSO / B - 11754/2R1)

2.3.2 Open web steel girders - Truss type with riveted construction/welded construction

Mostly all spans of 30.5 m and above are of open web steel girders in railway track bridges. Open web girders are used as (a) deck type (underslung of 30.5 m span as standard girder and above that, spans are of nonstandard design) (b) Semi through (non-standard) (c) through standard spans of 30.5, 45.7, 61.0 and 76.2 m. Nonstandard open web girders are of many types as indicated in Fig. 1.5 to 1.13.

Warren truss (triangulated truss) with vertical members at every panel point is used as standard through and deck type girder for track bridges. Figure No.2.8 indicates types of truss.

Mostly open web type girders are used for track bridges over valleys and large rivers on account of economy in cost. This is achieved due to low depth of bottom of girder from the rail level (for through girder bridges). Presently steel used is conforming to IS: 2062 Grade 'B0' for rolled sections and rivet steel conforming to IS: 1148 for spans of 30.5, 45.7, 61.0 and 76.2 m. Steel used for rail cum road/rail bridges truss with riveted construction of for spans 91.5 and 122.2 m is conforming to IS: 8500 (old IS: 961) for rolled sections. For welded floor systems such as cross girders and stringers steel is conforming to IS 2062 Grade 'B0' and rivet steel confirming to IS: 1149.

Design of open web girder for primary and secondary stresses is as stipulated in the Indian Railways Steel Bridge Code Clauses 3.3.1 and 3.3.2.

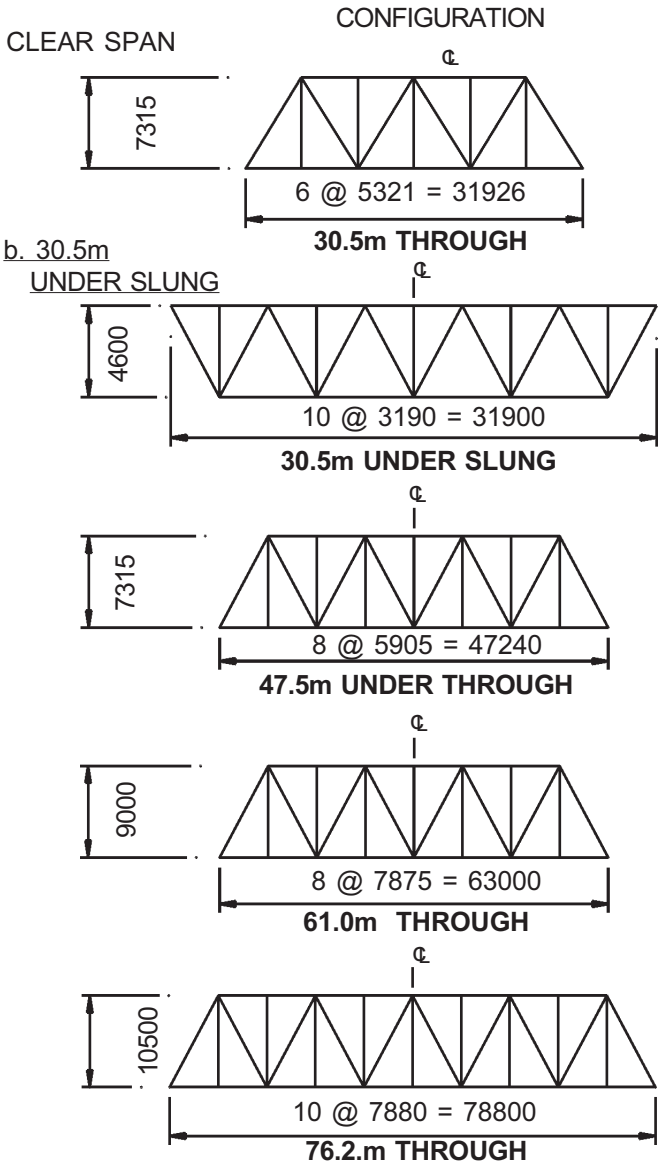


Fig. 2.8 Configurations of broad gauge standard open web girders.

Clause 3.3.1 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.

Clause 3.3.2 Secondary stresses - In practice the assumptions made in Clause 3.3.1 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.

Girders are designed, fabricated and erected in such a manner as to minimise secondary stresses as far as possible.

In nonprestressed girders, deformation stresses mentioned in Clause 3.3.2 (b) of Steel Bridge Code shall in the absence of calculations be assumed to be not less

than 16.67% of the dead load and live load stresses including impact. Now with computer aided design (CAD) it is possible to calculate all stresses by "3D" analysis with the end conditions defined.

In case of prestressed open web girders deformation stresses may be ignored, hence as per Steel Bridge Code clause No.3.3.9 all open web girders for railway track bridges of span 30.5 m and above shall be prestressed for achieving saving of steel due to ignoring deformation stresses. Since the method adopted on Indian Railways is holding good with economical maintenance, therefore, it is continued till date. Rules for prestressing are given in Appendix "A" of Steel bridge code. In actual sense it is predeforming of members to ensure that under full load (i.e. Dead Load + Live load + Impact) the members along their centrodial axis are of nominal lengths (without any deformation).

Method of fabrication and erection for achieving prestressing in the open web girder is as under:

I. During fabrication

(a) Marking and drilling of holes in the main gusset plates of each panel points of top and bottom chord, is to be done on nominal layout as per details of joints indicated in fabrication drawing so as to preserve the intersection angles of nominal profile (uncambered profile) corresponding to fully loaded state of truss.

(b) Length of all members of truss are to be fabricated to camber lengths as indicated in camber sheet of fabrication drawing, with the group of connection

holes at both ends drilled through holes of main gussets which are drilled on nominal layout. For this purpose, hole drilling jig is to be manufactured for each member with the distance between the group of end holes altered by the amount of camber allowance, i.e. difference between nominal length and camber length.

(c) Bottom chords camber length are same as nominal length to facilitate the fabrication of stringer.

II. During erection (assembly) at site

The work is to be done in successive stages so as to prestress (predeform) the members of truss, that is to say members of erected truss in the unloaded state is a reverse way to what would have happened to them under full load if the truss were designed and erected without prestressing. Assembly procedure in stages to be adopted for site assembly is mentioned in para 2.6. Fig. 2.14 indicates the stages of erection for prestressing.

Track structure over the stringers or top chord is provided with the same thickness of sleeper throughout the length of span hence track will have the same camber profile of truss during unloaded state.

2.3.2.1 Open web through girder (standard span)

Camber sheet of fabrication drawings of all open web girders indicates the designed camber at each panel point (based on joint deflection calculated by Williot diagram) and altered camber length as well as nominal length of

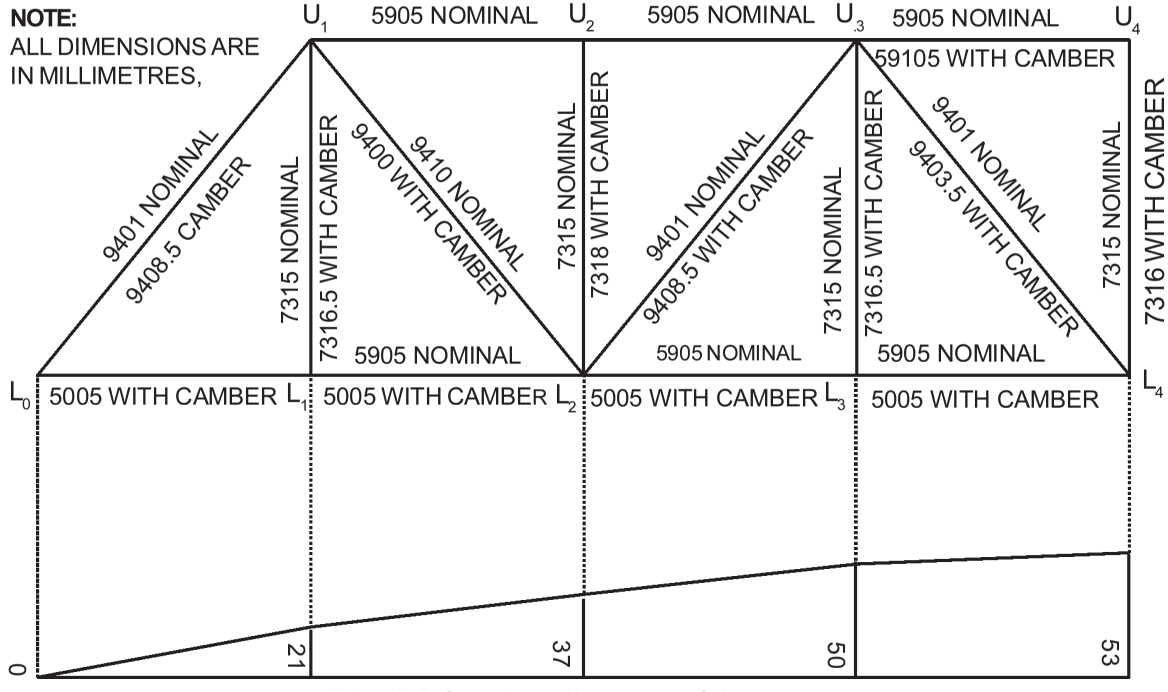


Fig. 2.9 Camber diagram of 45.7 m span

each members of truss. Fig. 2.9 shows details of each member camber length and nominal length of span 45.7 m for guidance.

Stress sheet of open web girders indicates the members, maximum force in members, nature of stress and cross section area required and provided. Table 2.4 shows sample of a part of stress sheet of 61.0 m span for guidance.

All bottom chord panel points are designated as L_0, L_1, L_2, L_3, L_4 etc. upto the last panel (L stands for Lower chord panel) and all top chord panel points are designated as U_1, U_2, U_3, U_4 etc. upto last panel (U stands for Upper chord). This facilitates identifying each member. L_0, L_1, L_2 are numbered in increasing direction of kilometre. (Fig. 2.10)

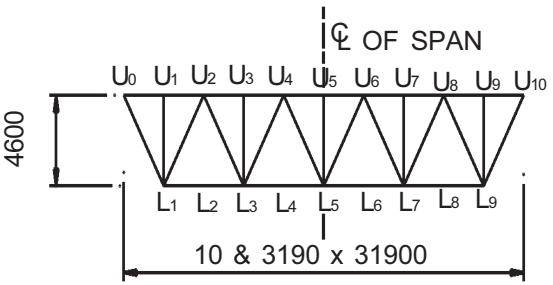
In open web girders of through type, centre to centre of trusses and height of truss is governed by the schedule of moving dimensions rather than structural design requirement; hence the floor system is essentially required for track structure support. This is consisting of cross girders and stringers (rail bearers). The distance between rail level to bottom of girder varies from 1232 to 1777 mm for spans 30.5 to 76.2 metres.

Main components of open web through spans - Riveted construction

a) Bottom chord - Tension member designated as L_0- L_1 or L_0- L_1- L_2 etc. and made up of 2 nos. rolled or built up channels back to back placed at a distance apart and connected with batten plates to form a member. To

Table 2.4: Stress sheet for 61.0 m span

MEMBER	MAXIMUM FORCE IN TONNES	SECTION PROVIDED (IN MILLIMETRES)
$L_0 - L_1$	+ 180.0	4 ANGLES 150 x 115 x 10 2 SIDE PLATES 630 x 8
$L_1 - L_2$	+ 180.0	4 ANGLES 150 x 115 x 10 2 SIDE PLATES 630 x 10
$L_2 - L_3$	+ 420.16	4 ANGLES 150 x 115 x 10 2 SIDE PLATES 630 x 16 2 SIDE PLATES 630 x 10
$L_3 - L_4$	+ 420.16	4 ANGLES 150 x 115 x 10 2 SIDE PLATES 630 x 16 2 SIDE PLATES 630 x 12
$L_4 - L_5$	+ 500.65	4 ANGLES 150 x 115 x 10 4 SIDE PLATES 630 x 16
$U_1 - U_2$	- 321.35	4 ANGLES 150 x 115 x 10 2 SIDE PLATES 630 x 10 1 TOP PLATE 660 x 8
$U_2 - U_3$	- 321.35	
$U_3 - U_4$	- 480.90	4 ANGLES 150 x 115 x 10 2 SIDE PLATES 630 x 10 2 ADDL. PLATES 330 x 10 1 TOP PLATE 660 x 12
$U_4 - U_5$	- 480.90	
$L_0 - U_1$	- 311.20 -13.70	4 ANGLES 150 x 115 x 10 2 SIDE PLATES 630 x 10 2 ADDL. PLATES 330 x 10 1 TOP PLATE 660 x 12
$U_1 - L_2$	+ 251.74	4 ANGLES 100 x 100 x 10 2 SIDE PLATES 500 x 12
$L_2 - U_3$	- 193.40	4 ANGLES 100 x 100 x 10 2 SIDE PLATES 400 x 12
$U_3 - L_4$	- 3.26 + 139.48	4 ANGLES 75 x 75 x 10 2 SIDE PLATES 350 x 12
$L_4 - U_5$	+ 44.63 - 89.87	4 ANGLES 75 x 75 x 10 2 SIDE PLATES 300 x 8
$U_1 - L_1U_3$ $- L_3U_5$ $- L_5U_2$	+ 85.15	4 ANGLES 75 x 75 x 10 WEB PLATES 370 x 18
$- L_2U_4$ $- L_4$	- 6.90	



30.5 M. SPAN
UNDERSLUNG TYPE
(BA - 11401)

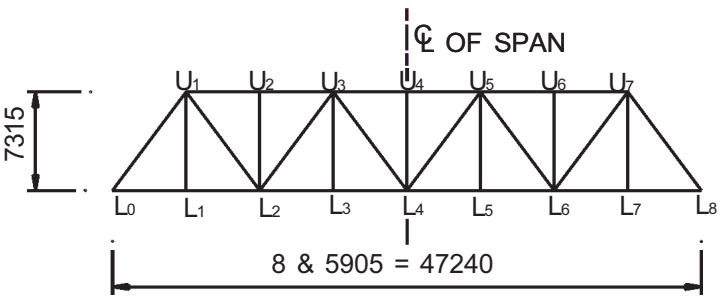


Fig. 2.10 Numbering of panel points

increase cross section for middle chords additional web plate is provided with riveted connection.

b) Top chord - Compression member designated as U_1-U_2 or U_1-U_2-U_3 etc. and made up of 2 nos. rolled or built up channels and top flange plates. Channels are placed with distance apart back to back and top flange plates are connected to top leg of channels with rivets and bottom legs of channels are connected with batten plates and lacing to form members. Diaphragms are provided in the webs with riveted connections. To increase the cross section for middle chords additional side plates as well as increased thickness of top flange plates are provided with riveted connection.

c) End Rakers - Inclined members at either end of the truss, i.e. L_0-U_1 are called as end raker. It is a compression member and heaviest member of truss. From of this members is the same as that of top cords. This member in addition, transfers racking force and wind force, etc. to bearings.

d) **Diagonals -** All intermediate inclined web members are called diagonal members. First diagonal member U_1 - L_2 is tension member and second diagonal member L_2 - U_3 is compression member. Further, alternately the members are compression and tension upto the centre of span. Also these members experience some amount of opposite nature of stress (compression member will have tensile stress and vice-versa) as per occupation of load on span. Hence these members are also called as reversible stress members. These members consist of channels either rolled or built-up face to face, kept apart and connected with batten plates and lacing with rivets.

e) Vertical members - All vertical standing web members are called vertical members. Members connecting odd number panel points (i.e. L_1-U_1) are tension members and members connecting even number panel points i.e. U_2-L_2 are called redundant members as they carry only dead load stresses and provide rigidity to truss and reduce unsupported length of top chord. These members are made up of web plates and 4 nos. of angles with riveted connections to form I-sections as components.

Following are the members of floor system of through span:

1) Cross girders - Each panel point of bottom chords of both trusses are connected by cross beams called cross girders. This member is built up I-section like plate girder, with web plate, top and bottom flange angles and flange plates with angle stiffeners of riveted connection. On either end of cross girder, angle cleats are provided for connection with main truss panel points (bottom chord). Both the end cross girders are provided with additional stiffeners and pad plates for lifting the girders by jacks for maintenance work. Remaining cross girders are called intermediate cross girders.

2) Rail bearers or stringers - Between two cross girders one set of built-up I-section-like plate girder is provided called rail bearer or stringer. Both ends of stringer are connected to cross girder web by stiffener with rivets. Only 3rd rail bearers from either ends for span 61.0 and 76.2 m are connected one end to cross girder with rivet and other end is resting on brackets provided in web of cross girder to act like free end to avoid distortion of bottom chord under load. Stringers consist of web plate and flange angles with riveted connection to form I-section as members. Cross

frame or diaphragm with lateral bracing are provided to stringers for lateral rigidity. Sleepers rest on top flange stringers and are anchored with hook bolts.

Secondary members

Secondary members are those which can be replaced by themselves individually. Following are the secondary members of open web through spans:

(a) Bottom lateral bracings
(b) Top lateral bracings
(c) Sway bracings and knee sway
(d) Portal bracings and knee portal
(e) Corner brackets
(f) End stools and end bracket
(g) Main gussets
(h) Bearings

Bottom lateral bracings are made up of 2 angles built in star shape with batten plates (riveted connections). These are provided in each panel (below rail bearer) and diagonally connected to bottom chord panel points with lateral bracing gussets. These bracings are connected with hanger plates to bottom flanges of rail bearers to transfer the longitudinal forces to bottom chord panel points.

Top lateral bracings are made up of 2 angles built up in star shape with batten plates or light frame shape and these are provided in each panel (between sway bracings) and diagonally connected to top chords with top lateral

gusset plates to resist wind force as well as for lateral rigidity.

Sway bracings are made up like light frames with top and bottom flange angles with lacings and batten plates in webs with riveted constructions. These are provided in webs of top chords at intermediate panel points for lateral rigidity. One strut is provided between bottom flange of sway connected to the vertical and is called knee sway bracing.

Portal bracings are made up of beam type or frame type and connected at either end panel points partially to top chord and partially to end raker. Knee portal struts or frames are connected to end rakers. Corner brackets are made up of web plates and angle cleats connected to top flanges of cross girders at ends and corresponding vertical members at intermediate panel points for lateral rigidity as well as to avoid tensile forces coming in rivets, connecting cross girders to panel points near top flanges.

End stools made up of web plates and angle cleats are provided to end panel point of bottom chords in line with the cross girder and forms diaphragm to afford rigidity at Last panel point in lieu of vertical member.

End brackets made up of web plates and angle cleats are provided to end cross girders in line with the stringers to one end of a span in multiple span bridge or at both ends in single span bridge. This ensures proper sleeper spacing.

Main gussets are made up of 20 mm thick plates for connecting members at every panel point of top and bottom chords.

Bearings of open web through spans are provided with one end as free end for expansion and these bearings are called as rocker and roller bearings. Other end of span is provided with fixed end bearings called as rocker bearings with grillage. Bearings are connected with turned bolts between saddle plate and bottom chord at either end. All shop rivets in main truss and floor members are of 20 mm dia. driven in 21.5 mm dia holes. All field rivets of trusses are of 22 mm dia. driven in 23.5 mm dia. holes. Fig.2.11 & 2.12 show the details of open web through span.

2.3.2.2 Open web deck type span (underslung)

Standard span is 30.5 m and spans above 30.5 m are nonstandard spans. These spans are also of riveted construction and fabricated as prestressed open web girders. Trusses are in inverted shape and are below the track structure. Sleepers are directly resting on top chords and hence no floor system like cross girders and stringers is required. Centre to centre of the trusses is 2300 mm and truss height is as per design requirement. Therefore underslung girder span of 30.5 metres requires 30% less steel than 30.5 metres through span. These spans are used for bridges over valleys and viaducts where waterway is not the criterion, thus achieving economical bridge construction.

Camber and stress sheets are provided in the set of drawings indicating camber at each panel point and cambered length of each member to be fabricated.

Following are the main components of underslung open web girder.

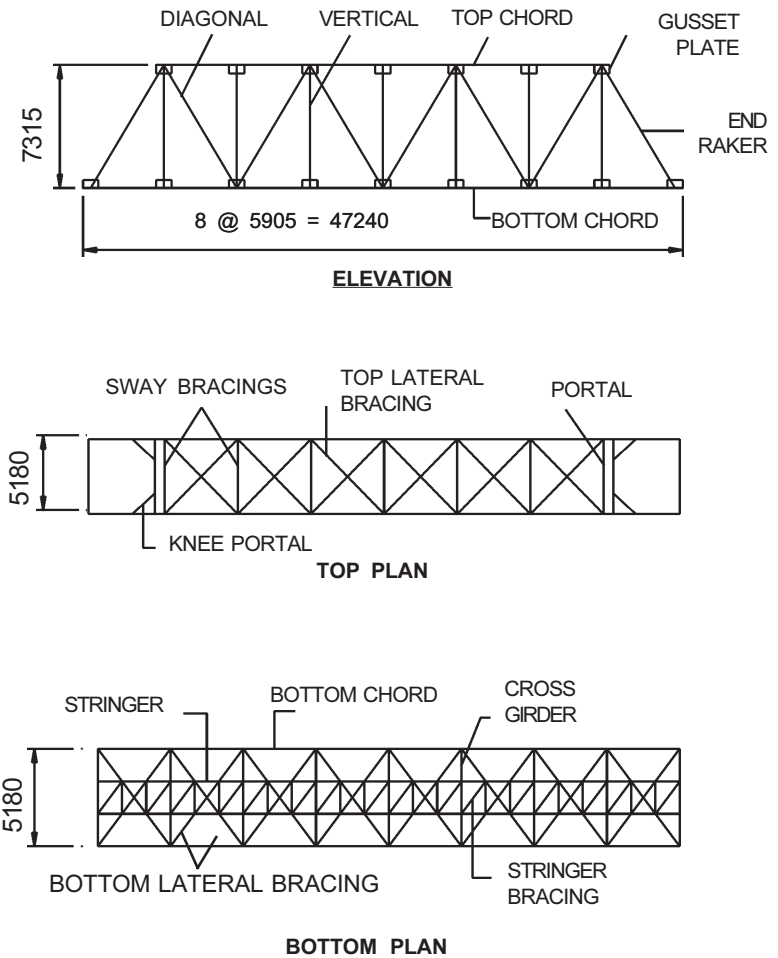


Fig. 2.11 Main elements of open web girder

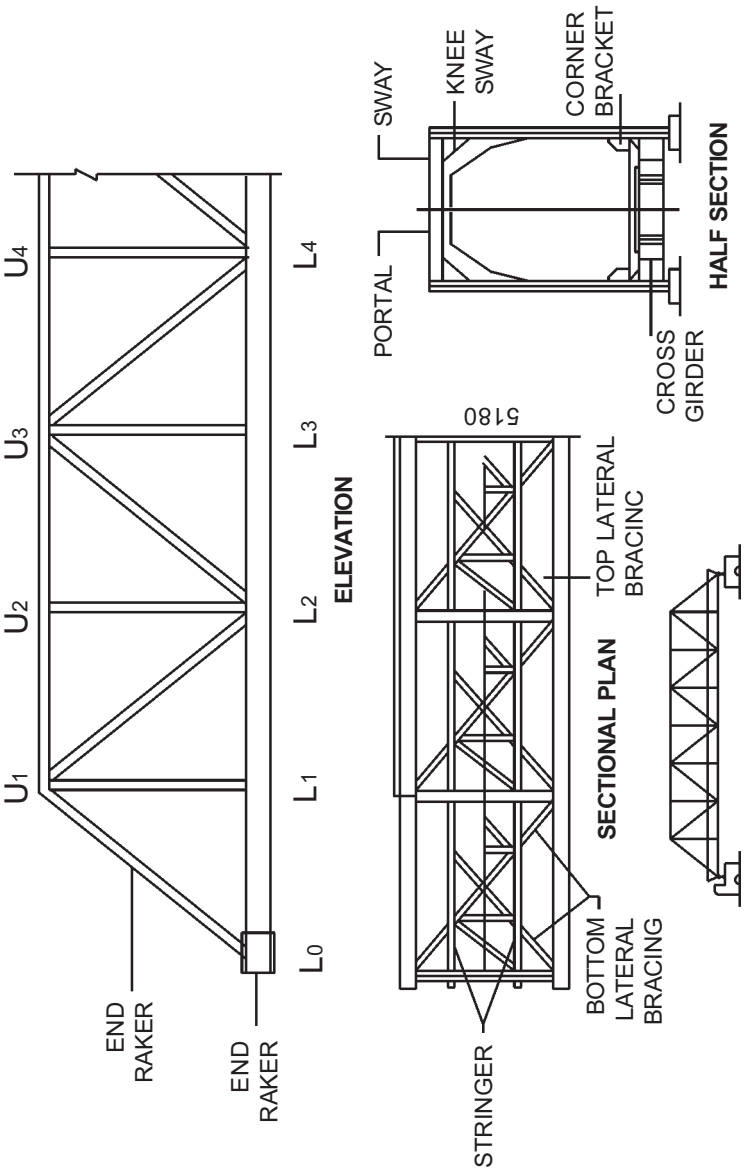


Fig. 2.12 RBG Standard 45.7 m span of open web girder (through)

(a) Top chord compression members designated as U_0-U_1, U_2-U_3, etc. Construction is similar to top chord of through span

(b) Bottom chord tension members designated as L_1-L_2, L_2-L_3, etc. Construction is similar to bottom chord of through span.

(c) End diagonal tension members designated as U_0-L_1 or L_9-U_{10}. These members consist of 2 rolled channels back to back placed apart connected with batten plates to form members like bottom chord of through span.

(d) Intermediate diagonal members are alternately compression and tension like through span and are also reversible stress members. Members are made up of rolled channels similar to diagonals of through spans with battens/lacings connected to channel top & bottom legs with rivets.

(e) Vertical members are compression members provided at only odd number panel points as U_1-L_1, U_3-L_3, U_5-L_5, etc. These are built up I-sections similar to through type girder.

Secondary members are as follows:

(i) Top lateral bracings

(ii) Bottom lateral bracings

(iii) Cross beams

(iv) Cross frames (Sway bracing)

(v) Bearings

Top lateral bracings are provided diagonally (in horizontal plane) between top chord panel points. These consist of double angles and gusset plates (star shape).

Cross beams (diaphragms) are provided at every panel point of top chord. Intermediate members consist of single rolled channels and end members at panel point U_0, and U_{10} are provided like beams made up of 2 rolled channel back to back with stiffeners to facilitate the lifting of girder by jacks during maintenance work.

Cross frames (sway bracings) are provided between verticals and end diagonals and consist of angles for horizontal and diagonals (in two panels).

Bottom lateral bracings are provided diagonally to bottom chord. Underslung girders are provided with sliding type bronze bearings. One end of span is free end and knuckle plate slides over bronze plate provided on base plate. Other end of span is fixed end and knuckle plate is riveted to base plate. Rotary movement is provided on either end with chamfered bearings over knuckle plate. These bronze bearings need not be greased but cleaned once in 3 years to avoid damage to smooth surface of bronze plates.

For underslung girders also structural steel used is the same as through spans conforming to IS: 2062 Grade B0 for rolled sections and rivet steel is IS: 1148.

Sleepers are directly resting on top chords of the girders and hence called deck type. Fig. 2.13 indicates details of underslung girder.

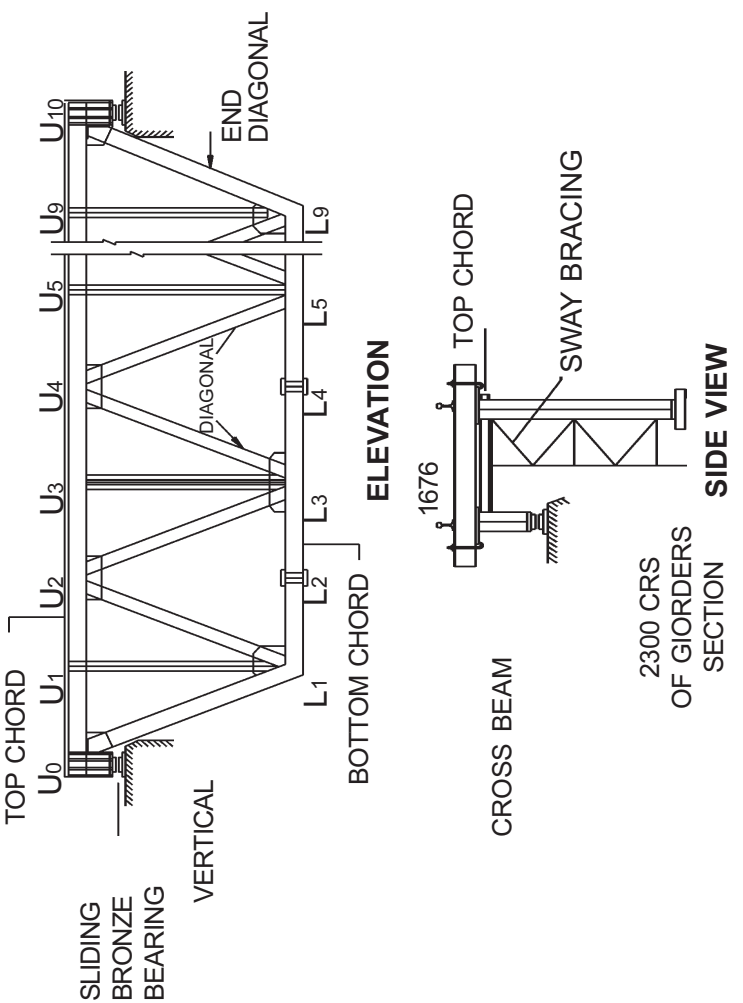


Fig. 2.13 R. B. G. Standard 30.5 m span (underslung span)

2.4 PROCEDURE FOR ERECTION OF OPEN WEB STEEL GIRDER FOR TRACK BRIDGES AS 'PRESTRESSED' (PREDEFORMED) GIRDER

To ensure truss under full load (DL + LL + DA) to remain in nominal profile, following procedure is to be adopted for erection (assembly) at site.

This procedure will however not apply in case, erection of girder is carried out by cantilever method, since members undergo reverse stress during erection, i.e. top chord which is designed as compression member is under tension and bottom chord designed as tension member is under compression. During cantilever erection, position of joint holes should not be disturbed by reaming. After erection of each member, flairing of connection holes by drifting and riveting of joints is done simultaneously, to achieve camber as well as prestressing.

2.4.1 Erection stages

(i) Erect assembly platforms 600 mm high below each bottom panel point of both trusses over well compacted ground to avoid settlement during erection.

(ii) Place camber jack (screw jack) over platform below every bottom panel joint of both trusses in such a way that all jacks are in run out condition except centre jack i.e. at least 15 mm more than the amount of lowering required to provide design camber, stipulated in camber sheet at every panel point. Ensure top of all camber jacks in one level.

(iii) Place all bottom chords of both trusses over camber jacks as well as cross girder, rail bearer, bottom lateral bracing fixed in position, in one level condition with min. 40% black bolts and 10% drifts. This will not pose any problem for erection as camber lengths of bottom chords are same as nominal lengths. Rivet all panel point, rivets connected to bottom chord & main gusset. During riveting ensure one level by frequent checking with dumpy level and staff. Details indicated in **Stage I of Fig. 2.14.**

Erect all web members i.e. vertical & diagonal except end rakers (End Post) of both trusses & rivet the bottom connection with gusset of panel points of bottom chord. Since holes drilled on member connecting gusset as well as panel points gussets are marked and drilled on nominal layout it will not pose any problem in fairing holes for riveting. Top of web members should be provided with wire rope guys for stability. On the other end (top connection) of web members, i.e. diagonal & vertical erected should be connected with temporary gusset drilled with camber profile holes or provide permanent gussets (holes drilled on nominal layout) of top chord panel point with undersize bolts temporarily. Check to ensure that the bottom chord is in one level. Details as per **Stage II of Fig. 2.14.**

Provide camber to all panel points of bottom chord as given in camber sheet by lowering the jacks below respective panel point. For this operation it is easy to lower the jack than lifting hence keeping centre jack without disturbing, lower other jacks (lowering is maximum at ends). Check the camber readings and adjust for correctness. Details as per **Stage III of Fig. 2.14.**

All top chord & web members are to be elastically strained into position by external force so that as many holes as possible are fair or the top chord should be erected piece by piece working symmetrically starting from centre outwards & fair the holes with gusset by using split drift in number of holes and hammering with 1 kg hammer simultaneously to strain the member under close expert supervision. (If temporary gussets are used, these should be replaced by permanent gusset before drifting). Ensure maximum number of holes are drifted simultaneously. The effect of drifting being checked by observation of adjacent unfilled holes. Complete the erection of top chord. Details at **Stage IV & V of Fig. 2.14.**

Either side end post shall be erected at last. The upper end of end post connection should be made first & drift the lower connection holes last and rivet all top chord panel points after erection of sway bracing, top lateral and portal bracings. Details as shown in **Stage VI of Fig. 2.14.**

After entire riveting of joints, support the span at ends on bearings by removing all intermediate supports. Check dead load camber, which will indicate the reduction of camber proportionate to dead load. Dead load camber of each span should be recorded in camber register to compare the camber recorded during maintenance inspection. Table 2.5 shows design camber of 30.5, 45.7, 61 and 76.2 m standard through spans.

NOTES

1) During service if a web member is damaged by external hitting or snapping of web member resulting in loss of camber at any panel points, the rectification of damaged web member or replacement of web member with correct

camber as original, is only possible by supporting all panel points and cutting of all panel joint rivets and again erecting in same sequence as mentioned above for prestressing. This will require closure of line for longer period or taking out span from the road with provision of temporary girder and crib. It will be economical to replace the girder with new one and use the reclaimed girder for branch line. However, if camber is not affected and only web members are damaged, the members can be rectified or replaced one by one with procedure ensuring that no loss of camber occurs during rectification or replacement of the member.

2) Camber in steel truss girder is provided upward amount being equal to deflection of girder under design load during fabrication and erection so that girder under full load, truss shall be in horizontal plane (nominal shape). The girder is laid out and fabricated to cambered profile. Such girder will get deformation stresses under load. Such type of cambered steel truss girders are used for FOB on Indian Railways.

3) Steel truss of foot overbridge is fabricated on camber layout as cambered truss but no prestressing is required. Hence above procedure should not be used.

4) Prestressing of open web steel girder of track bridge is predeforming of members during fabrication and erection of girder to ensure girder under full design load shall be in nominal shape to minimise deformation stresses. When correctly erected, such predeformed girder gets dead load camber.

5) As per Steel Bridge Code [Clause No.4.17] for permanent installation other than foot over bridges, the ratio of deflection to length of girder shall not exceed L/600.

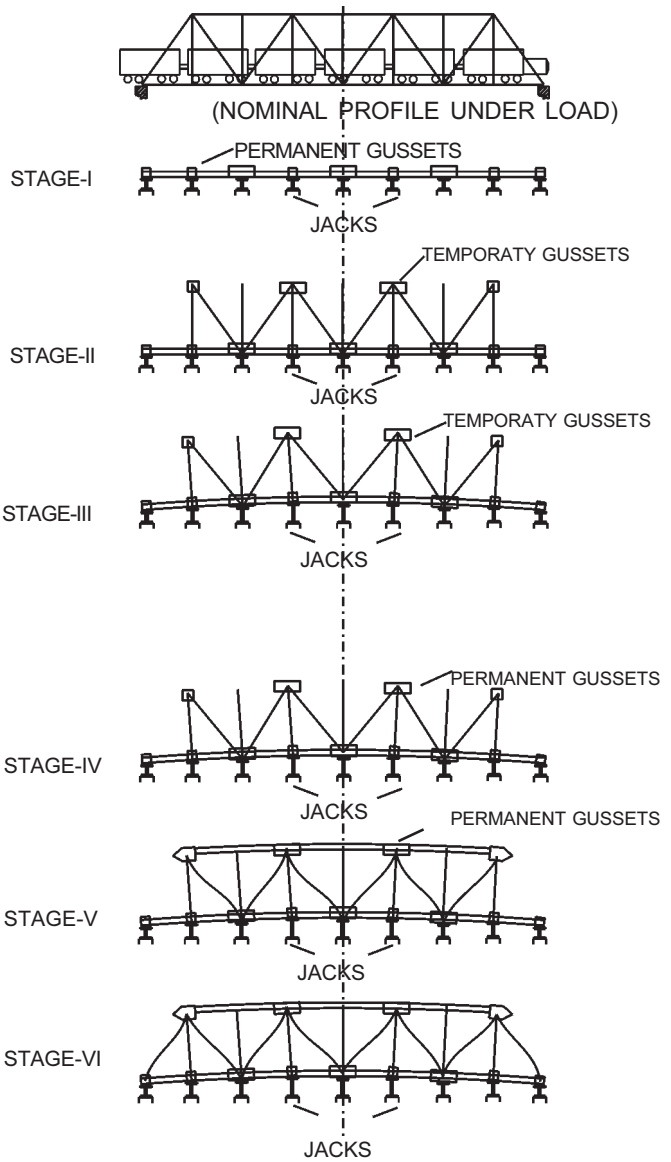


Fig. 2.14 Erection of open web girder 45.7 m standard span

SPAN	DRG No.	L_0	L_1	L_2	L_3	L_4	L_5	REMARKS
30.5 m	BA-11464/R	0	13.100	21.000	26.300	---	---	MBG Welded Type Girder
45.7 m	BA-1148/R	0	22.000	38.000	52.000	55.000		
61.0 m	BA-11583/ R	0	30.360	53.730	71.770	76.040		
76.23 m	BA-11804/R	0	36.130	66.540	92.820	106.060	113.610	
45.7 m	BA-11363	0	23.00	40.000	55.000	57.000		MBG Riveted Type Girder
61.0 m	BA -11323	0	32.500	57.000	76.500	81.000		
76.23 m	BA-11153	0	35.000	62.500	88.000	101.000	108.000	
30.5 m	B-17163	0	11.000	17.500	22.000			25t LOADING Welded Type Girder
45.7m	B-17181	0	16.500	29.500	40.000	42.000		
61.0 m	B-17023	0	27.160	46.199	62.471	65.412		
76.23 m	B - 17043	0	31.000	55.090	76.200	87.100	94.150	
30.5 m	B - 17063	0	10.3374	15.7329	20.2764			32.5t AXLE LOADING Welded Type Girder
45.7 m	B - 17083	0	15.500	25.000	35.000	36.000		
61.0 m	B - 17123	0	26.740	45.340	61.720	64.790		
76.23 m	B -17103	0	31.733	54.215	74.154	83.657	88.802	
30.5 m	BA-11523 / R	0	13.880	22.870	22.490			HM LOADING Welded Type Girder
45.7 m	BA - 11503	0	23.000	34.800	48.600	53.600	-	
61.0 m	BA - 11553 / R	0	32.749	55.609	74.626	78.123	-	
76.23 m	BA-11624 / R	0	37.600	67.350	93.290	105.680	114.170	

Table 2.5 Design load camber of RBG / MBG / through span steel girder

Table 2.5 (a) Design load camber of RBG / MBG / Underslung span steel girder

SPAN	DRG. No.	U_0	U_1	U_2	U_3	U_4	U_5	U_6	REMARKS
30.5 m	BA- 11403	0	13.250	23.170	30.070	33.920	36.000	-	RBG Riveted Type Girder
45.7 m	B-11643	0	14.521	18.128	39.311	47.662	53.834	54.887	
61.0m	BA-11663	0	25.100	48.000	66.300	75.300	78.300	-	MBG Welded Type Girder
30.5m	B-17163	0	7.650	14.200	19.460	21.420	.23240	-	25t Loading Welded Type Girder

2.5 ROAD OVER BRIDGES (ROBs)

As the name implies, the structure crossing the railway track and carrying road way above is called a Road Over Bridge. The portion of this ROB structure within the Railways jurisdiction is almost invariably constructed and maintained by the Railway administration, the remaining portion being left to the custody of State Govt. or local body as the case may be.

In the olden days Road Over Bridges were constructed with steel girders over which the roadway passes. However as the concrete technology developed, the construction of ROBs has been switched over to RCC & PSC girders thereby resulting in saving in maintenance expenditure. Recently railway has adopted composite girders for ROB. New girders are being connected using high strength friction grip (HSFG) bolts. The HSFG bolt are discussed at the end of this chapter.

Following types of steel girders have been used for ROBs on Indian Railways:

1) Deck type

Main girders are of steel and road deck is of R.C.C. forming a monolithic composite structure. The R.C.C. road deck is on the top flanges of girders with suitable effective anchorage. Fig. 2.15 shows details.

2) Semi-through type

a) Main girders are of steel plate girder, placed at adequate distance apart, connected by cross girders and road bearers with jack arches on road

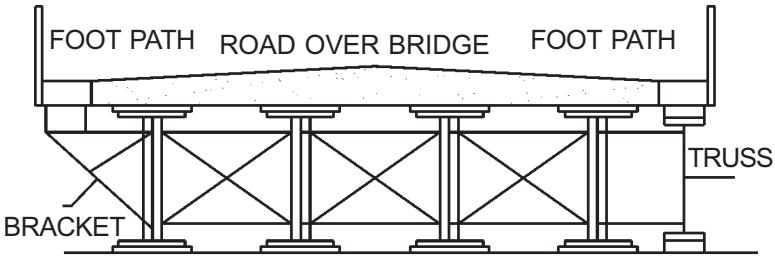


Fig. 2.15 ROB deck type

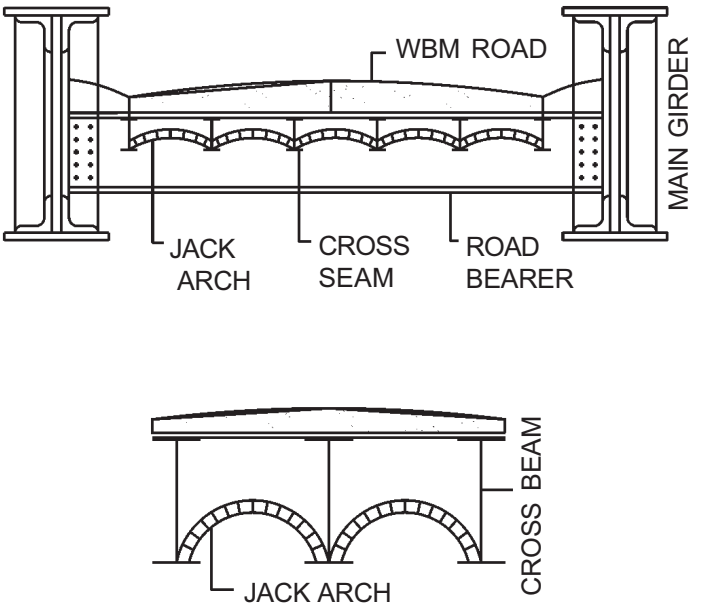


Fig. 2.16 ROB jack arch deck type

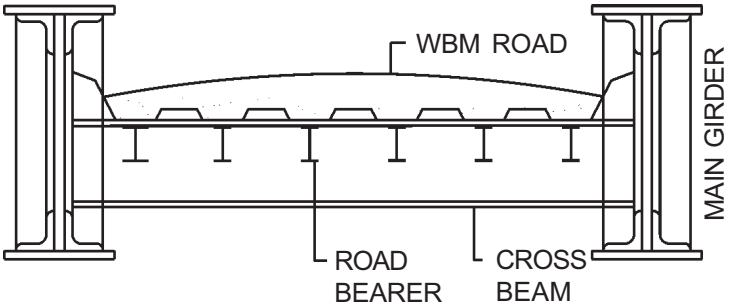


Fig. 2.17 ROB Semi-through

bearers carrying the requisite road way. Fig. 2.16 shows details.

b) Main girders with cross girders and road bearers and steel troughs over these cross-girders and road bearers filled with road material and forming the roadway. Fig. 2.17 shows details.

c) Main girders with cross girders and road bearers over which concrete slab rests, forming the road way portion. Fig. 2.18 shows details.

3) Through type

Steel girders of through type with the floor system (cross-girders and road bearers) carrying the concrete road slab forming the road way.

2.5.1 Deck type ROB

Generally, the main steel girders of these ROBs are plate

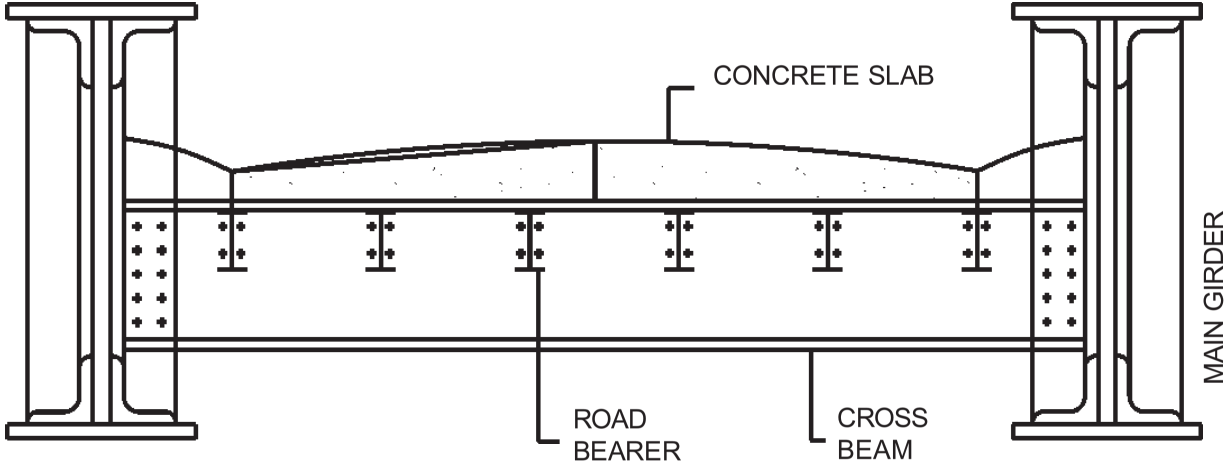


Fig. 2.18 ROB-Semi through (with concrete slab deck)

girders identical to track bridge girders and designed to carry IRC loading. However, since the road vehicles run on rubber tyred wheels, the ROB structure suffers quite a low impact due to air wheels. These girders are therefore designed with much less dynamic loading.

However after year 1950 or so the ROBs constructed are mostly of deck type with 4 or 6 nos. of longitudinal steel girders depending on the width of the road and the road concrete slab cast on the top of these girders. Footpath is provided on brackets fitted to outer-most girders outside or a truss is provided to support foot-path.

2.5.2 Semi-through type ROB

Earlier ROBs were mostly semi through type provided with jack arches supported on cross-girders or road bearers, and even water bound macadam road was made on this. On some ROBs steel troughs have also been provided over cross-girders and road bearers to carry the macadam road.

2.5.3 Bearings of ROB

All plate girders of ROBs whether deck type or semi through type are provided with phosphor bronze bearings since it is not feasible to lift these girders periodically for greasing.

Through type ROB girders are provided with rocker and roller type bearings.

2.5.4 Expansion joint

Expansion joint is provided at either end of the approaches

on single span and at either end of the girder for multiple span bridge. But it is observed that, over the years these expansion joints get jammed by asphalt due to frequent road surface maintenance. Thus new designs of expansion joints are being evolved.
With the past experience, it is observed that the rivets in ROB girders seldom get loosened but corrosion does occur on rivet heads due to accumulation of water and muck. Hence systematic and effective painting is a must to keep the girders functioning for long years as designed (70 to 80 years).

Kerb bent plates are generally provided to main plate girders along the inner side of the road to prevent the road vehicles hitting the main girders.

Most of the ROB plate girders are of riveted construction and no camber is provided to these girders.

2.6 FOOT OVER BRIDGES (FOBs)

The foot over bridge steel girders are the light structures spanning on the railway stations from platform to platform for facilitating the commuters to cross over from one platform to another. These consist of main girders and staircase stringers, providing ramps or steps for the passengers to climb up from and step down to the platforms either for alighting or for entraining.

FOB's old steel girders are in the form of either lattice through girders or 'N' type through girders or pin connected triangulated Warren girders, etc. The main girders support the road path for passengers to walk. This road path rests on the floor beams connected to main girders horizontally leaving a gap of about 50 mm between the road edge and

the innermost members (bottom flanges) of the main girders to avoid accumulation of muck and water and thus prevent corrosion and to ensure effective minimum maintenance.

The staircases are made up of stringers and risers with angles and plates for supporting in situ cast RCC steps or pre-cast RCC steps. To avoid steep climbing, the staircase is generally made in two flights with an intermediate landing. This relieves the passengers of strenuous climb to a great extent.

Theses girders are fabricated in lengths commensurate with the no. of tracks to cross in the station yard. These were fabricated as riveted construction prior to year 1970 and subsequent to year 1970; welded construction has been resorted to. These are predominantly statically loaded structures and hence the camber provided is for dead load + 75% of live load without impact. Its deflection under designed load should not exceed L/325 where L is the length of the girder. For plate girders upto 35 m length span (115'-0"), no camber has to be provided as per Steel Bridge Code clause noA.16.1 but all truss type girders are provided with camber and fabricated on camber layout. Hence called cambered truss (whereas trusses for track bridges are not only cambered trusses but are also prestressed). Steel used for these girders conforms to IS-2062 Grade 'A' for both riveted and welded construction.

In the olden days the girders were made to rest on masonry substructure and the staircases were in the form of ramps or steel stanchions with risers and steps made of cast iron treads perforated to avoid corrosion and to reduce weight.

Presently the girders are fitted to RSJ columns on the platform to which the staircase stringers are also attached. The steel columns are located on the platforms on sound foundations, care being taken to avoid infringement to moving dimensions. Mostly pre-cast slabs of RCC are used for main floor as well as steps for staircase stringers. To avoid wear and tear of the edges of the steps, nosing angles are fitted to the edges of these steps thus prolonging its life and obviating escapable maintenance.

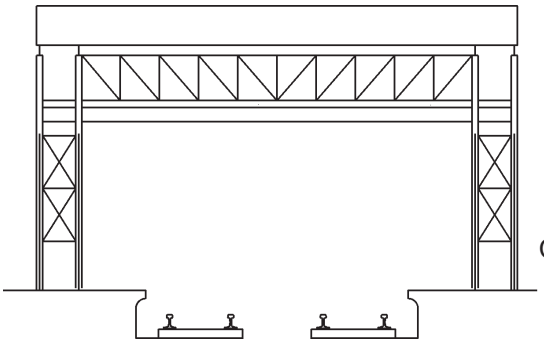
No moving bearings are provided to these girders (girders are bolted to the columns) hence no greasing is necessary. It has been experienced that the occurrence of loose rivets or weld cracks in these girders and staircases is almost nil. Other aspects of inspection and maintenance are namely floor slab, staircase steps, roof sheeting and protection frames in electrified areas. These are maintained by SE/JE Works concerned. (Fig. 2.19 indicate typical F.O.B.)

2.6.1 Beam type FOB

In this type RSJs or welded built up I-girders are used as super structure with portal frames erected on brackets connected to the outside of outer girder for hand railing and roof cover. R.C.C. deck is cast in situ or pre-cast slabs fixed on top flanges of girders without shear connectors. Stiffeners are provided to beam. Main girders rest on cap beams of columns. Fig. 2.19 shows details.

2.6.2 Portal type FOB

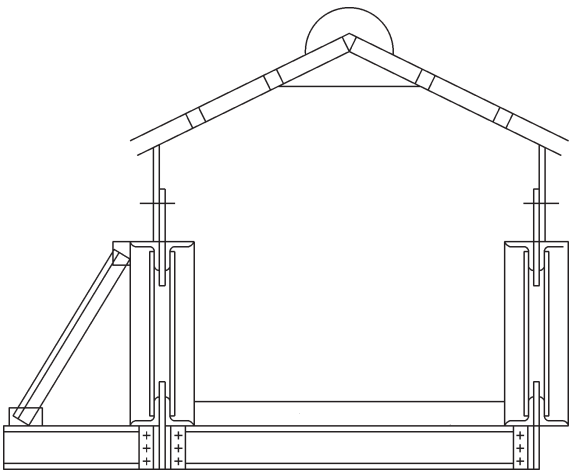
This is a portal rigid frame type structure in which the main girders are spliced to columns to form one unit. Other



CROSS SECTION
(OLD TYPE)

ELEVATION

FOOT OVER BRIDGE
'N' TYPE TRUSS



CROSS SECTION OF FOOT OVER BRIDGE
(NEW TYPE)

Fig. 2.19 Foot over bridge 'N' Type truss

items are same as mentioned in para 2.5.1. Fig. 2.20 shows details.

2.6.3 Truss type FOB

2.6.3.1 Pin connected triangulated girders

These are mostly wrought iron girders released from British Railways track bridges and used on Indian Railways as FOBs. In these pin connected girders some alterations had to be made so as to use these girders as FOB girders. Accordingly hanger plates are connected at each pin joint of bottom chord and floor beams are connected to these hanger plates. The floor beams in turn carry the floor slab either cast in situ or precast R.C.C. segments. The main girder ends are provided with steel bracket with pins to rest on masonry sub-structure or on column caps. Roof trusses provided to these girders act as top bracings with raker brackets (Fig. 2.21 shows details).

2.6.3.2 Lattice type truss

These girders are formed by top and bottom flanges out of angles back to back and M.S. flats diagonals in the shape of diamond openings for web. Floor beams are fitted to bottom flanges from underneath, below the stiffener at each panel point. Earlier these girders were designed for wooden floors which were later on replaced with concrete slab deck. This change has over stressed some of the girders which lost their camber due to incresed dead load and had to be subsequently strengthened. These types of FOB girders are now obsolete. (Fig. 2.22 shows details).

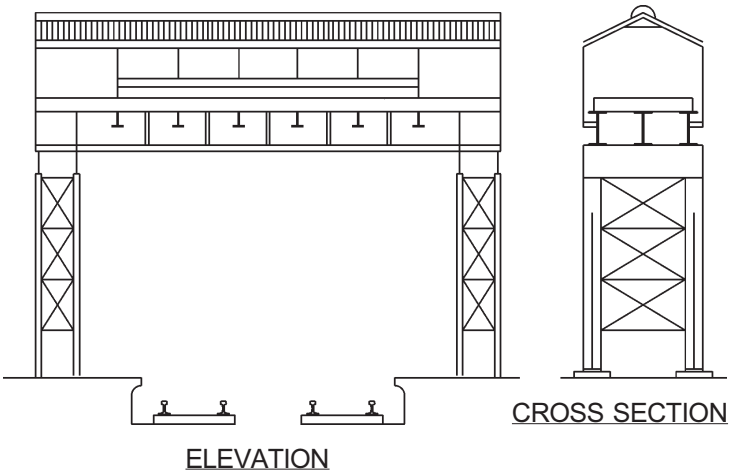


Fig. 2.20 (a) Foot over bridge - Beam type (welded construction)

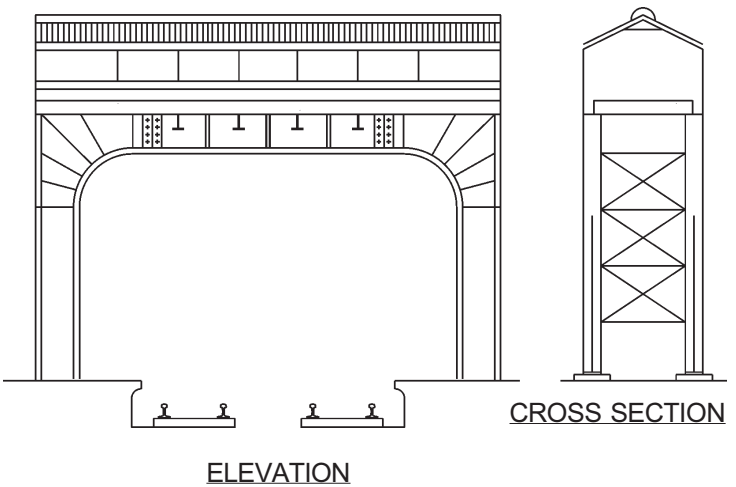


Fig. 2.20 (b) Foot over bridge - Portal type

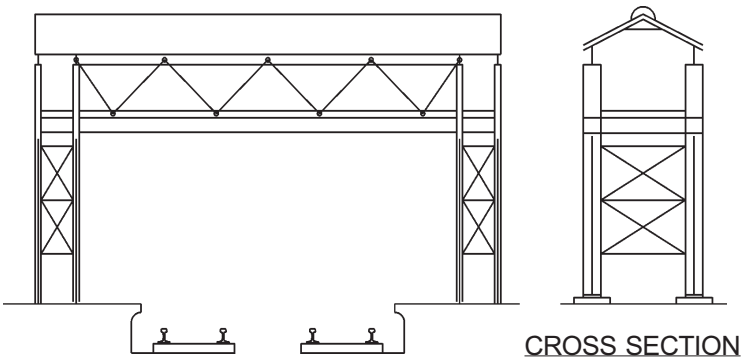


Fig. 2.21 Foot over bridge - Pin connected (old)

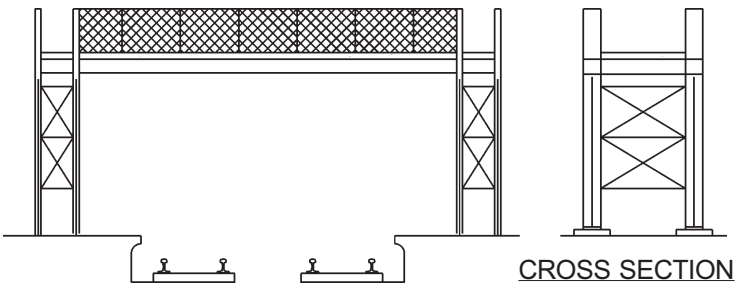


Fig. 2.22 Foot over bridge - Lattice type (old)

2.6.3.3 'N' Type truss

These FOB girders consist of 'N' type trusses made of top and bottom flanges out of angles back to back with gussets in between these angles to which verticals and diagonals are welded, forming an 'N' truss. Floor beams were directly attached to the bottom of bottom flanges by bolts and the concrete slab rests on the floor beams as well as bottom flanges of main girders directly. This arrangement posed a maintenance problem because due to stagnation of rainwater at the junction of floor beams and main girders heavy corrosion is caused. This arrangement was therefore modified by protruding the main gussets down below the bottom flanges of main girders and floor beams are connected to these gussets by bolts and the concrete slab is resting on these floor beams only, thus leaving the main girders unaffected. This arrangement has reduced the maintenance work to a great extent and the corresponding expenditure. The cavities formed in the stringer channels and the columns base should be filled with concrete to avoid water accumulation and subsequent corrosion. The sub-structure in this type of FOB is made of steel columns (R.S.J's) called tower columns (consists of four nos. for main column at ends and two nos. for intermediate column) duly braced with angle bracings and firmly bolted/ riveted. The main girders are connected to these columns at top to give adequate clearance from rail level to bottom of the girders as per provision of schedule of dimension.

The main girders are bolted to main column with adequate no. of bolts in addition to resting on brackets attached to the columns. (Resting the girders on these brackets on columns will relieve the tension on the bolts connecting girders to columns to a great extent). Rakers are provided

to the truss girders at every alternate vertical from outside to afford sufficient lateral stability to the trusses. Bottom lateral bracings are provided between floor beams and bottom booms of main girders for lateral rigidity. Roof truss is fitted to every panel point of top boom which acts as top bracings and the roof sheeting is provided to these trusses by fixing runner angles. Fig. 2.19 shows details.

The length of FOB girders depends upon the no. of tracks to be covered plus minimum moving dimensions from the nearest track to the nearest columns. Similarly the height of FOB girders from R.L. is guided by schedule of moving dimensions including those in electrified areas. The widths of the FOBs are 2.4 metres, 3.6 metres, 4.8 metres depending on the density of commuter traffic.

The modified 'N' type FOB truss retains the accessibility of all the steel work which would certainly make it possible for these structures to be inspected and maintained by SE/JE Works. Since FOBs are located on the station platforms, no trolly is required and the SE/JE (works) can easily maintain these structures.

2.6.4 Quadricon type FOB

Quadricon FOB girders (patented) are in the form of triangulated span and connections at joints are made by Quadricon patent male and female connections with centre bolts. It is a unit type construction. To the male and female component like diagonals and top and bottom members are welded forming a triangulated girder. This facilitates adoption of incremental launching in situ over the tracks without interfering with the traffic. At one approach half the span is erected and from there, further erection proceeds panel by panel, as joints being

connected by males and females with centre bolts. Members are quite light in weight and can be manually handled. In this type of girder no repairs are generally needed.

2.6.5 Fabrication and erection of FOB

Important aspect to be considered for fabrication and erection of FOBs are -

i) Fabrication for welded beam or truss type steel girder shall be confirming to IRS - B1 and welded bridge code provisions.

ii) Truss type girder are provided with camber hence fabrication has to be carried out on camber profile through jig and fixture.

iii) Since truss is designed as uniformally distributed loaded truss, pre cast slabs are to be laid starting from both ends towards centre to avoid buckling due to concentrated load (if loaded in centre of span leads to accident).

iv) If RSJ columns are used with end bolted connection of truss to top, first ensure straightness of columns. After erection of columns check with plumb for verticality and centre to centre distance of columns before erecting both trusses.

v) After erection of both trusses provide floor beams, end raker, bottom lateral bracing roof truss (if it is there) and tighten all bolted connections.

vi) Check the verticality of columns with plumb and camber of truss. Then grout the anchor bolts after tightening all bolts connections to truss and bracings.

vii) When anchor bolts are set, start laying of pre cast slab from both ends of spans towards centre.

2.7 CONNECTIONS USING HIGH STRENGTH FRICTION GRIP BOLTS

High strength friction grip (HSFG) bolts and nuts are made of high strength structural steel. They are tightened so as to induce predefined tension in the bolt shank and the plies are joined without any gap. Due to this high frictional force is generated at the interface between the plies and they cannot move relative to each other. The load transfer mechanism is shown in Fig.2.23. The HSFG bolts are direct replacements of rivets and with proper design, the number HSFG bolts in a joint/ splice shall be less than or equal to the number of rivets. HSFG bolts has following benefits:

I. Reduced time of assembly / erection.

II. Reduced requirement of scaffolds.

III. Less skilled manpower requirement.

IV. Less rejections and easier supervision.

V. Providing quality HSFG bolts is feasible as compared to other alternatives:

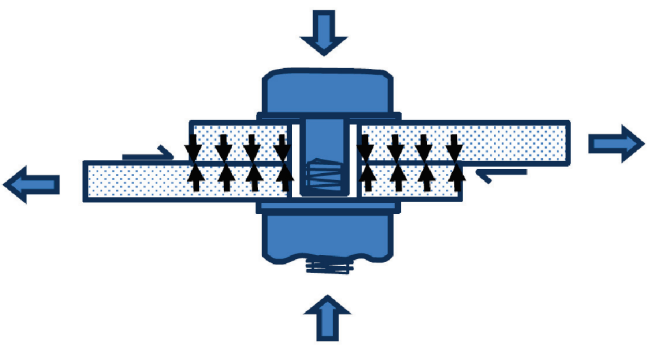


Fig.2.23 (a) HSFG bolt action friction along interface transfers shear load.

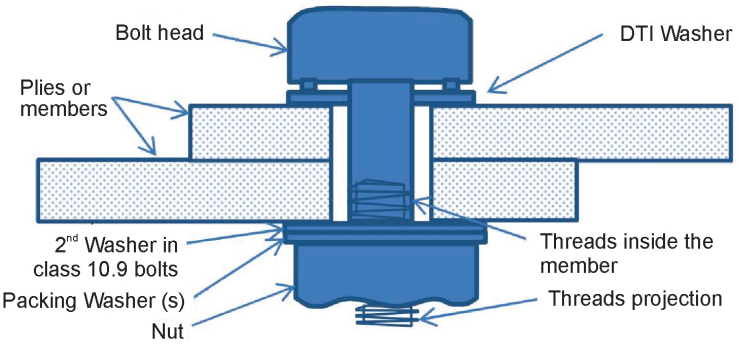


Fig.2.23 (b) Typical sketch of HSFG bolt

High Strength Friction Grip (HSFG) bolts shall be provided as per para 28.9 of IRS - B1-2001 (Specification For Fabrication And Erection Of Steel Girder Bridges And Locomotive Turn Tables (Fabrication Specification)). These bolts shall be designed as per provisions of IS: 4000-1992 (High Strength Bolts in Steel Structures - Code of Practice) with the over-riding clauses as mention in BS111. Provisions not covered in IS: 4000-1992 shall confirm to IRS Codes. For edge distance, gauge distance and Pitch etc., provisions of para 7 of BS 111 shall be followed. Joints with HSFG bolts shall be designed only as friction type joints. Bearing type joints with HSFG bolts shall not be provided. Short / Long slotted holes shall not be allowed.

Bolts and nuts shall conform to IS: 3757 and IS: 6623 respectively. The threads in nut shall be matching with the threads of the bolt and nut shall be strong enough to impart the necessary torque to the bolt. Normal height of the nut shall be more than 0.8 times and nominal bolt diameter. The length of bolt shall not exceed 10 times the

nominal diameter of the bolt. All bolts and nut shall be supplied with coating consisting of zinc phosphate which is used in conjunction with suitable rust preventive oil as per IS: 1367 (Part XII).

Washers for HSFG bolts shall conform to IS 6649. Washers are annular rings which are provided between the bolt head / nut and the members being joined. Washers could be of different types e.g, plain, packing, hardened, tapered or Direct Tension Indicators (DTI).

2.7.1 Property class - The property class is defined by IS: 4000 for both bolts and nuts; it has two parts which is separated by a decimal i.e. in the form "X · Y". The first part, "X" indicates 1/100 of the nominal tensile strength in Newton per sq mm and "Y" indicates ten times the ratio of the lower yield stress and nominal tensile strength. For example, property class "8.8" means that the bolt will have nominal ultimate tensile strength of 800 N/mm^2, and lower yield stress of 80% of 800 N/mm^2, i.e. 640 N/mm^2. The property classes specified in IS: 1367 (Part 6) and suitable for HSFG connections are "8.8" and "10.9". The nuts shall be hardened and then tempered at a temperature of at least 425°C.

2.7.2 Identification - The property class shall be embossed or indented (e.g. 8.8 or 8S), along with manufacturer's identification symbol (ABC) on the top of head, on the top or the bottom face of double chamfered nuts and on non bearing surface of washer faced nuts. The Suffix's here denotes that the bolt is high strength structural bolt with a large series hexagon.

2.7.3 Anti – sabotage and anti – theft measures – HSFG bolt cannot be opened out except by use of torque

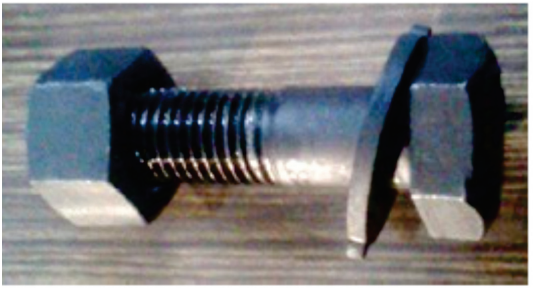


Fig 2.24 Bolt assembly



Fig 2.25 Actual bolt head with marking

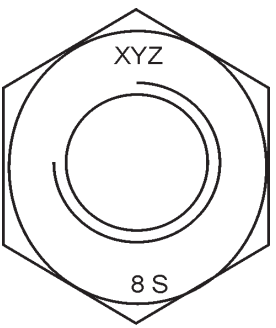


Fig 2.26 Typical sketch of nut head with marking

wrench. Still, as an additional precaution, it may be ensured that the nut is not easily accessible for opening out by anti-social elements. The nut shall be provided towards outer side of web of the girder; towards bottom of the flange but in composite construction towards inside of concrete. In bracing the nut shall be provided towards the rolled section side so that the space for rotation of the nut is not readily available. Where tapered washer is used, the nut shall preferably be on the other side. In addition to this, the bolt threads may be destroyed by applying tack welding to the bolt projection beyond the nut after final tightening and inspection. The tack shall not be more than 5 mm long and not more than 3 mm in size. Alternatively, use of proven bonding agent to seize or lock the bolt in position may be applied to the threads projecting beyond the nut.

2.7.4 Holes for HSFG bolts - Diameter of hole shall be 1.5 mm plus the bolt diameter upto 25 mm diameter bolts. For larger diameters HSFG bolts hole shall be 2 mm more than nominal diameter of HSFG bolts. When the bolts are to be provided in existing structure, the maximum size of hole shall not exceed 1.25 d or d + 4 mm whichever is less i.e. for 16 mm dia. bolt, the maximum diameter of hole shall not exceed 20 mm. If diameter of hole exceeds the bolt diameter by 2 mm, hardened washers shall be used in place of normal washers.

2.7.5 Surface preparation for steel interface before providing HSFG bolts - The steel interface between the plies must have slip factor as assumed by designer. Following special surface preparation shall be done:

a) **New construction -** The interface between the plies which are connected together by the HSFG bolts shall be "Aluminum metallised without any over coating". The aluminum metallising shall be as per para 39.2.1 of IRS B1.

b) **Existing structures-** The interface of plies shall be cleaned as specified in IRBM para 217, 1 (b), (i) to (iv). If in existing structures, rivets are to be replaced by HSFG bolts but no surface preparation is possible, then the slip factor shall be suitably reduced.

2.7.6 Installation of bolts - The tightening of HSFG bolts is a highly skilled technical procedure. Trained and certified personnel shall be allowed to carry out the installation of HSFG bolts. The competency certificate shall be issued by an engineer not below the rank of ADEN and certificate shall be revalidated at every six month.

2.7.7 Torque wrench- Certified Mechanical torque wrenches (pneumatic, hydraulic, electronic etc) shall be used for tightening of bolts. For small quantum of work, manual torque wrenches may be used is shown in Fig.2.27.



Fig.2.27. Torque wrench

2.7.8 Calibration and torque setting for torque wrench-

Torque wrenches shall be calibrated once in a year to an accuracy of ±10%; as per procedure specified by the manufacturer. It should be re-calibrated if the wrench fell / mishandled or the joint is found to have been improperly tightened.

In the torque wrench torque shall be set as per recommendations of bolt fabricator, but it shall be within limits specified in Table C1 of IS: 1367 (2002) part 8. Otherwise, torque to be applied shall be 10% less than the maximum value of torque given in Table C1 of IS: 1367 part 8.

2.7.9 Sequence of tightening - Following steps shall be followed for tightening of bolts:

1. The holes of the plies shall be aligned using drifts etc. without distorting / enlarging the holes.
2. The HSFG bolt shall not be forced into holes otherwise bolts threads will damage. The plies shall be held in position by partially tightening of few HSFG bolts. These bolts shall not be tightened to second stage till all the bolts in a joint are inserted and tightened to first stage.
3. Verify alignment / geometry of members w.r.t drawings.
4. Insert balance bolts and tightened partially.
5. Replace the drifts by HSFG bolts one by one.

Note: Due to tightening of bolts, the steel members may continue to deform, hence loosening of already tightened bolts. Therefore, tightening shall always to be done starting

from the stiffest part to the free edges. Stiffest parts of joint are generally around the center of the joint.

6. Tighten all the bolts to first stage of tightening.
7. Check for residual gap between the plies. If residual gap, is less than 2 mm at edges but no gap in the central portion than proceed to next stage of tightening. In case the central portion is not in close contact or gap at edges is more than 2 mm, open out all the bolts and straightening of plies to be done, after that repeat all the above steps.
8. Proceed for second stage of tightening as per the type of washer used.

2.7.10 Installation of HSFG bolts using Direct Tension Indicator - This is the preferred method of installation of HSFG bolts. The Direct Tension Indicators are special type of washers with projections which get pressed when tension is applied. The pressing of projections to required level indicates that the required tension has been applied in the bolts (Fig.2.28). Resemblance of DTIs with washers is incidental. In fact, DTIs are precision engineered mechanical load cell which is the most reliable method for checking HSFG bolt tensioning. As shown in Fig.2.29, the feeler gauge is to be inserted between the projections to check if the bolt has been sufficiently tightened or not.



Fig. 2.28 (a) Two faces of DTI

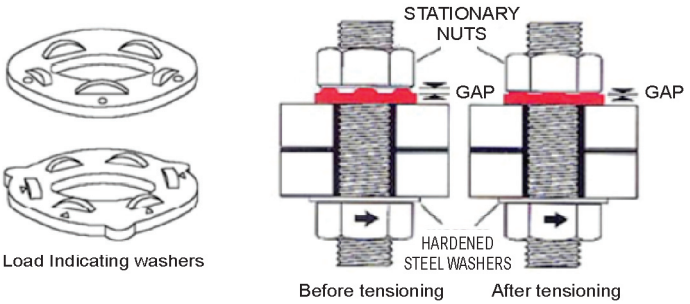


Fig. 2.28 (b) Direct tension indicator

2.7.11 Calibration of Direct Tension Indicator - Three sets of bolts of same diameter and similar property class shall be taken and installed with DTI. Installation procedure similar to that for plain washers are used for DTIs also. On full tightening, the projections on DTI washers shall meet the requirements of second stage tightening using DTIs.

2.7.12 Procedure - The tightening is done in two stages.

i) **First Stage of Tightening**- All bolts in a joint shall be tightened to 'snug tight' i.e. the nut is tightened

using an ordinary wrench by an average worker, applying maximum force on the wrench.

ii) **Checks after First stage tightening-** Check the joint for residual gaps between plies.

iii) **Second Stage of Tightening-** During the second stage of tightening, torque wrench is used to tighten the bolts until the indentations on the DTI indicate full tightening.

iv) **Checks after Second stage tightening-** Check for refusal of 0.40 mm thick feeler gauge for 100% bolts. Refusal of 0.40 mm thick feeler gauge means that it cannot be inserted in the space between indicator positions on a DTI. Check for full compression of DTI using 0.10 mm thick feeler gauge i.e. this cannot be inserted. A full compressed DTI indicate over tightening of HSFG bolt. Failing this test indicate over tightening or poor quality of DTI. The procedure for checking the proper tightening of bolt using DTI is shown in Fig. 2.29

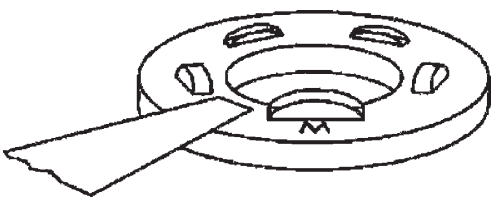


Fig 2.29 (a) Inserting feeler gauge in space between indicator positions

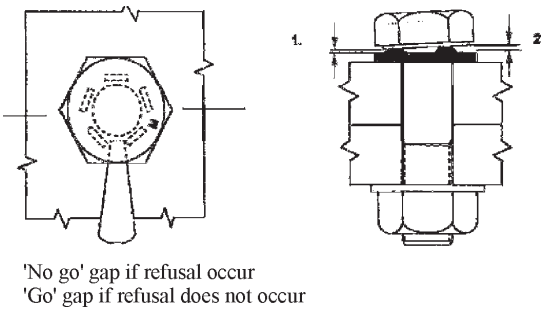


Fig. 2.29 (b) Method of checking the correct tensioning using DTI

2.7.13 Procedure for installation of HSFG bolts without DTI washers - If DTIs are not available then, plain washers may be used for installation of HSFG bolts after approval of SAG officer in-charge of the work, using the following procedure:

2.7.14 Procedure - The tightening is done in two stages.

1) **First Stage Tightening-** Calibrated wrench with an accuracy of ±10% shall be set to 75% of the torque computed for the complete tightening of the bolt. All the bolts shall be checked for tightness using this torque. After ensuring stage one tightness, permanent marks shall be made on the bolt and nut to establish relative position of the two.

2) **Checks after first stage -**

   i) Check the joint for residual gap in the plies.

   ii) 10 % bolts shall be checked with a separate

calibrated wrench set at 75% of the proof load for the bolt and any bolt turning by more than 150 during the same shall be rejected. If the loose bolts thus found are more than 5 but less than 1% of the total, another 10% of the bolts shall be checked. If the total loose bolts thus found exceed 1% of the total, the torque wrench shall be calibrated afresh and the entire lot shall be checked for tightness.

3) **Second stage tightening -** The bolts shall be further turned, by 60^0 if grip length is more than twice the diameter of the bolt, by 120^0 if the grip length is more than 6 times the diameter of the bolt if the grip length is between them by 90^0.

4) **Checks after second stage tightening-**

i) 100% bolts shall be verified for requisite amount of turning by comparing the permanent marks on the nut and the bolt.

ii) 1% of the bolts, subject to minimum of 10 per size of bolts shall be checked for gross under-tightening as per inspection procedure given in Annexure D of IS 4000.

2.7.15 Inspection of bolt tension using a Torque wrench as per Annexure D of IS: 4000 -

During inspection, the bolts shall be seen for the following:

a) **Broken/ missing bolts.**

b) **Loose bolts:** Looseness shall be identified by looking at the signs such as water ingress in the joint, signs of rust coming from inside the joint and fine powdery material coming out of joint etc. instead of by hitting the bolt.

Note – A suitable sample size would be 10 percent of the bolt, but not less than two bolts shall be used for inspection. This sample shall be tensioned in calibrating device.

c) A calibrated inspection wrench shall be applied to the tensioned bolt and the necessary torque which turn the nut / bolt head by 5 degrees (approximately 25 mm at 300 mm radius) in the tensioning direction shall be determined. The average torque measured in the tests of at least three bolts shall be taken as the "job inspection torque".

d) At Least three bolts, of the same size and condition as those are under inspection shall be placed individually in a calibrating device capable of indicating bolt tension. A hardened washer shall be placed under the part turned.

e) Where no nut or bolt head is turned by the "job-inspection torque", the connection shall be accepted as properly tensioned.

f) If any nut or bolt head is turned by the application of the "job-inspection torque" then this torque shall then be applied to all other bolts in the connection. All bolts, whose nut or head is turned by the "job inspection torque", shall be tensioned and re-

inspected. Alternatively, the fabricator or erector at his option may retension all of the bolts in the connection and then resubmit the connection for inspection.

g) If loose bolts are found, the same shall be marked by a round circle all around and shall be replaced expeditiously.

2.7.16 Re-tensioning of bolts

i) As the HSFG bolts are tightened beyond yield stress level which causes damage to initial few threads while transferring load. Its length increases permanently as compared to initial length. Therefore, a bolt completely tightened shall not be reused under any circumstances.

ii) The bolt tensioned completely can be identified by damage to the threads especially near the front end of nut where most of the load is transferred. The coating, if any, may also show signs of damage. The free running of the nut on the threads may also be affected.

iii) A fully tensioned bolt, opened out for any reason whatsoever, needs to be rejected along with the bolt, the nut, washer(s) and DTI(s) used on that bolt.

iv) Bolt which has been snug tightened or partially tightened and then opened out will not be considered to have been re-tensioned and reuse

of such bolts will be permissible in the same or different holes, as required.

2.7.17 Use of HSFG bolts for repair / rehabilitation works- A joint shall not have mixing of HSFG bolts and rivets etc. HSFG bolts cannot be used for replacement of isolated loose rivets. Surface shall be properly prepared and joint design shall be done based on design provisions as per para 7.12 of Steel Bridge Code. Particular care shall be taken regarding use of appropriate slip factor for the surface preparation done.

2.7.18 Painting during initial installation- In case of HSFG bolts with "Direct Tension Indicating" device, the final coat in field applied on complete structure may be applied on HSFG bolts also. In case part turn method of tensioning is used without "Direct Tension Indicating" device, the HSFG bolts shall not be painted and the permanent location marks made on the bolts shall be visible after one year of installation.

2.7.19 Painting in service- HSFG bolts shall be painted as per normal painting schedules and painting methodologies as specified in the Indian Railways Bridge Manual for the girder as a whole.

Do and Dont's for construction engineers

DOs:

1. Do ensure that all bolts, washers and nuts are accompanied by manufacturer test certificates and appropriate markings indicating that these bolts are as per relevant codes.
2. Do metallise the surface which is to be connected

by the HSFG bolts.

3. Do ensure that all bolts, nuts and washers are coated with zinc phosphate, sealed with suitable oil of rust-prevention type (Only DTIs may have other surface coatings as approved by the manufacturer).
4. Do make sure that there is proper storage arrangement for the bolts, nuts and washers away from moisture, rain, dust, dirt and sunlight.
5. Do clean and lubricate the bolt and nut threads if these are dirty.
6. Do ensure that the nut moves freely on the bolt threads.
7. Do use only calibrated torque wrench (Calibrated within last 1 year).
8. Do properly check the bolts after initial tightening and after second stage tightening.
9. Do ensure that protrusions of the DTI are towards the bolt head or towards the nut depending on whether the DTI is provided under the head or nut of HSFG bolt.
10. Do use tapered washers wherever required.
11. Do check the tightening procedure if bolt breaks during tightening operation. It obviously means that the bolts are being over-tightened.
12. Do tighten the bolts starting from the stiffest part (middle of the joint) to the free edges.
13. Do provide small welding tack after final tightening and inspection to damage the threads to prevent the bolt from being opened where threat of sabotage/ theft is apprehended.

DON'TS:

1. Don't paint the interface except metalising.
2. Don't reuse a bolt which has been fully tightened once.
3. Don't use rusted and dirty bolts.
4. Don't hammer the bolts to insert into holes.
5. Don't overheat the bolt while making welding tack as the bolt might get damaged.
6. Don't use uncalibrated Direct Tension Indicators.

■ ■ ■

CHAPTER 3

STEEL SLEEPERS FOR STEEL GIRDER BRIDGES

3.0 INTRODUCTION

Track structure on bridges is different from that on embankment. On Indian Railways track structure being used on bridges are of different type such as ballasted deck and open deck.

3.1 DECK BRIDGE

Ballasted deck bridge - Rails, fittings and sleeper used on bridges with ballasted deck are similar to the track structure on approach and embankment except additional provision of guard rails to prevent over turning of derailed rolling stock. This type of deck can be used over masonry arch bridge, RCC/PSC I girder/slab and box, composite girder, PSC I girder/PSC box girder. In olden days ballasted deck was used on bridges of steel girder by providing steel troughs (Fig.3.1). Such steel trough ballasted deck pose problem for maintenance as well as repairs to corrosion effected members hence this system of floor was discontinued, in this case track structure is same as on approaches with minimum ballast cushion of 300 mm below sleeper. The details of ballasted track structure is similar to that stipulated in para 263 of Indian Railway Permanent Way Manual.



Fig. 3.1 Steel trough ballasted deck bridge

Open deck bridge - From the Inception of Railway in India, wooden sleepers are being used to support rails on steel girders. Space between two sleepers is open hence called open deck (Fig 3.2). Wooden sleepers derives many advantages over other types of sleepers, on account of lighter weight for handling on bridges, easy in machining (including at site) for placements, minimum simple fittings to hold the rails as well as in maintenance repairs. Wooden sleepers offer greater resilience hence no rubber pad is used like in case of steel channel / H – Beam sleepers.



Fig. 3.2 Open deck bridge

On open deck steel girders the independent movement of rail and girder is required hence rail free fastening are to be provided. These are provided with rail screw/dog spikes and canted bearing plates over wooden sleepers (bridge timbers).

Due to scarcity of wood and restriction to use wooden sleeper on Indian Railways, steel channel sleepers were introduced as substitute to bridge timbers during 1992 as per RDSO, drawing No.RDSO-B-1636 and B-1636/1. Subsequently to minimize number of fittings and ease in fabrication and maintenance, revised drawings were issued by RDSO, drawing No. B-1636/R2 and B-1636/1/R2 for steel channel sleepers of 150x75mm size. Additional drawing No. B-1636/2 has also been issued with increased height of channel sleepers i.e. size 175x75mm to avoid thicker packing plates over top flange plate of plate girders of 12.2m, 18.3m and 24.4m spans. As an improvement over channel sleepers recently H – Beam section were used and Drg. No. RDSO / B – 1636 / 5 were issued during 2005 and sleeper size is 200 x 200 mm. H - Beam sleepers are to be fabricated and provided on steel girder bridges. These sleepers are expected to be economical in fabrication as well as in maintenance.

Steel sleeper will rest on top of steel girder and will be connected / fixed with help of Hook Bolt having elastomeric pad of 25 mm thick below these sleepers as per Drg. No.1636 / 5, depending upon the type of the girders, e.g. Deck or Through.

Deck Type - Plate girder and under slung open web girder. For plate girders, whether it is welded type or riveted type steel girder, sleeper will rest on top flange plate (crosswise) of both girders, and for open web (under slung) deck type

steel girder of 30.5m span on top boom of both trusses.

Through Type - For open web steel girder (either riveted or welded type) of span 30.5 m, 45.7 m, 61.0 m and 76.2 m including steel girder of any span, sleeper will rest on top flange plate of stringer / rail bearer on flooring system of through span.

3.2. STEEL CHANNEL SLEEPERS

3.2.1 Size and length of steel channel sleepers

Size- Following two types of steel channel sleepers are in use:

(1) 150 x 230 mm size of cross section. Cross section of sleeper will be 150 x 230 mm after fabrication as per Drawing No. B-1636/R2 & B-1636/1-R2, because rolled channel ISMC 150 x 75 is used.

(2) 175 x 230mm size of cross-section. Cross section of sleeper will be 175 x 230 mm after fabrication as per Drawing No. B-1636 / 2, because rolled channel ISMC-175 x 75 mm is used.

Length - Length of steel channel sleeper depends on the type of steel girder bridges which is shown in the Table 3.1

Table 3.1: Length of steel channel sleepers for different type of span

Type of girder	Span (m)	Length of steel channel sleeper (mm)
		MBG
Plate Girder Riveted	12.2	2440
	18.3	2440
	24.4	2550
Welded Plate Girder (A*)	12.2	2565
	18.3	2440
	24.4	2440
Welded Plate Girder (B*)	12.2	2725
	18.3	2535
	24.4	2475
Open Web Steel Girder through span either Riveted / Welded type	30.5	2440
	45.7	2440
	61.0	2440
	76.2	2440

Note: * The top flange plate of welded girder has different width at both ends and middle portion of girder as shown in Fig. 3.3. Therefore, Length of sleepers on A and B location are of different length.

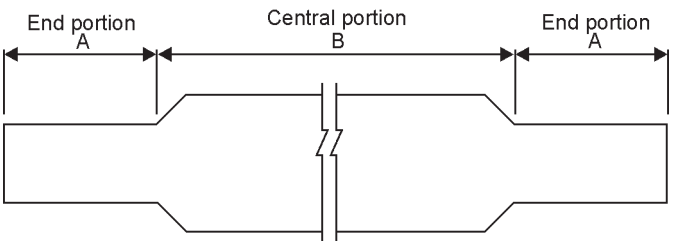


Fig. 3.3 Section of channel sleeper (150 x 230 mm)

However, Length of sleeper can be obtained as below:

Length of sleeper = Center to center length of girders + Flange width + 200/300mm

3.2.2 Details of steel channel sleeper

Shape of sleeper is made by 2 ISMC 150 x 75mm or 175 x 75mm, which are kept back-to-back 80mm apart to make width of 230 mm (Fig 3.4). Both channels are connected in web by 'T' and plate type diaphragms with fillet weld. 'T' shape diaphragms are connected below 'T' head bolt connecting rail clips. In case of loosening of nut, bolt will rest on 'T' diaphragm, so that clip will be in position as well as prevent falling down of bolt.

Canted bearing plates for rail seat are connected to top flange of both channels with rivets. Stiffener plates are provided below the rail seat with fillet weld in web between top and bottom flange of both channels as well as in the middle of sleepers. Details are shown in Fig. 3.5 (a) and 3.5 (b).

3.2.3 Track fittings for steel channel sleepers.

Steel Channel sleeper are provided with rail fastening arrangement to Drg No. RDSO/T-5155 to 5164 on BG (for 60 Kg running rail and 52 Kg guard rail) and to Drg No. RDSO/T-5197 to 5200 (for 52 Kg running rail and 52 Kg/ 90R guard rail). These fastening arrangements comprise of clips with T-head bolts and nuts to hold rail over steel channel sleepers through bearing plate and do not allow longitudinal movement of rail required for continuing LWR (Long Welded Rail) on girder bridges as per the stipulations contained in LWR manual.

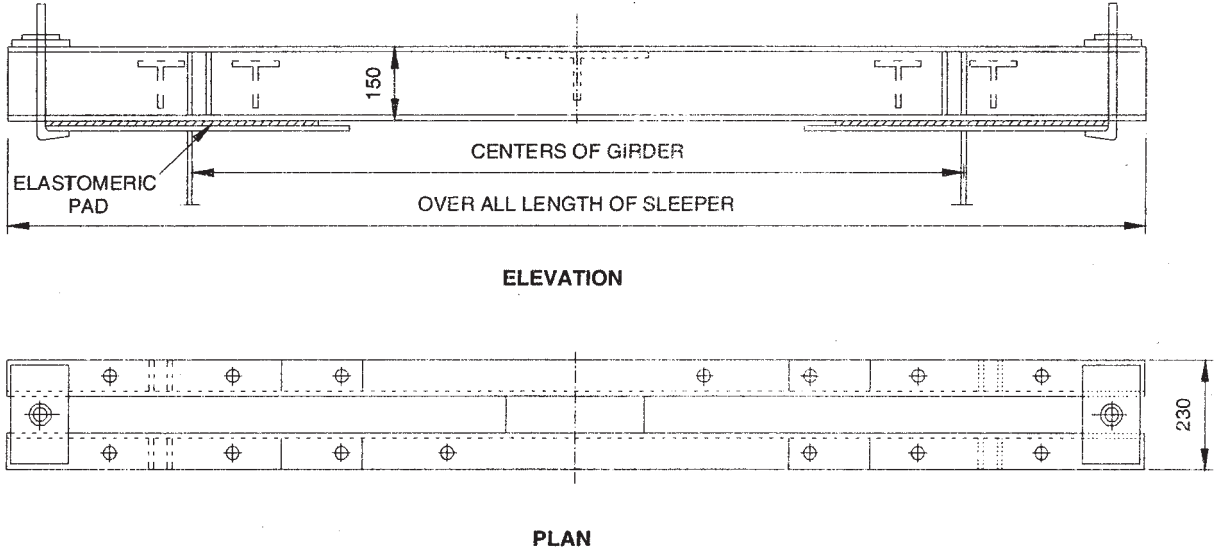


Fig. 3.4 Steel channel sleepers, BG

a) **Bolt-** 'T' head bolts with spring washers and nuts are used to clamp the clip to canted bearing plate to hold rails Fig. 3.6(a). 'T' head will facilitate insertion of bolt from top and vice versa removal of the same.

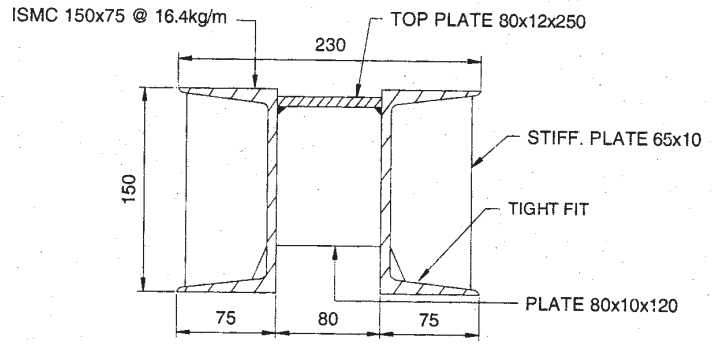


Fig. 3.5 (a) Section of channel sleeper (150 x 230 mm)

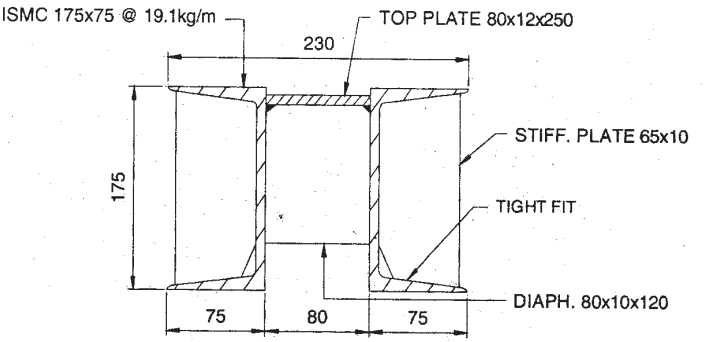


Fig. 3.5 (b) Section of channel sleeper (175 x 230 mm)



Fig. 3.6 (a) 'T' Bolt

b) **Clips**- Either side of rail clips are provided and tightened with 'T' head bolts to keep the rail in Position i.e. clip prevent lateral movement and uplift of rail but it will allow rail to move longitudinally to facilitate free movement of rail and girder as rail free fasteners Fig. 3.6(b). Guard rails are also anchored with both sides (crosswise) by bolt and clip to sleeper top flange.

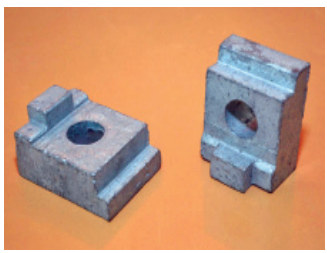


Fig. 3.6 (b) Clip

c) **Rail Pads -** Grooved rubber pads are placed bellow the rail on canted bearing plates. A 10 mm GRSP of suitable size is to be provided between

rail and sleeper Fig. 3.6(c). To provide smooth surface between rail and pad 2 mm stainless steel plate is embedded in rubber pad.



Fig. 3.6 (c) Rubber pads

3.3 H - BEAM STEEL SLEEPERS

3.3.1 Size and length of H-Beam sleeper

Presently, ISHB – 200 is used as H-Beam, which is suitable for Welded Plate Girders / Stringers of standard spans. The cross section of sleeper is 200 mm x 200 mm, as per Drawing No. RDSO / B-1636 / 8. In the riveted plate girders same type of H-Beam steel sleeper with same fixing arrangement shall be used. The length of the H- Beam sleeper as per Drg. No. RDSO / B 1636 / 5, varies as per the type of girder bridges are shown in Table 3.2.

Table 3.2: Length of H- Beam sleepers for different type of span

Type of girder	Span (m)	Length of H - Beam Sleeper (mm)		
		Loading Standard		
		BGML	25 t	DFC
Welded Plate Girder	12.2	2655	2705	2655
	18.3	2715	2715	2835
	24.4	2905	2905	2925
Welded Open Web Girder	30.5	2515	2525	2605
	45.7	2515	2565	2565
	61.0	2515	2655	2655
	76.2	2515	2655	2655

3.3.2 Details of H-Beam steel sleeper

H-Beam Steel Sleeper is made up of ISHB 200 and schemetic diagram is shown in Fig.3.7. This H-Beam consists of:

a) **Stiffener plates-** These are welded on both sides with top flange of H-Beam in full length and with web portion of the H-Beam upto a depth of 168 mm. The stiffener plate shall be having a tapered cut beyond 168 mm depth and shall tight fit with the bottom flange without welding as shown in the Drawing No. RDSO / B-1636 / 8 which is suitable for welded plate girders / stringers where there is no splice joint.

b) **Rail fastening assembly-** Position of holes on

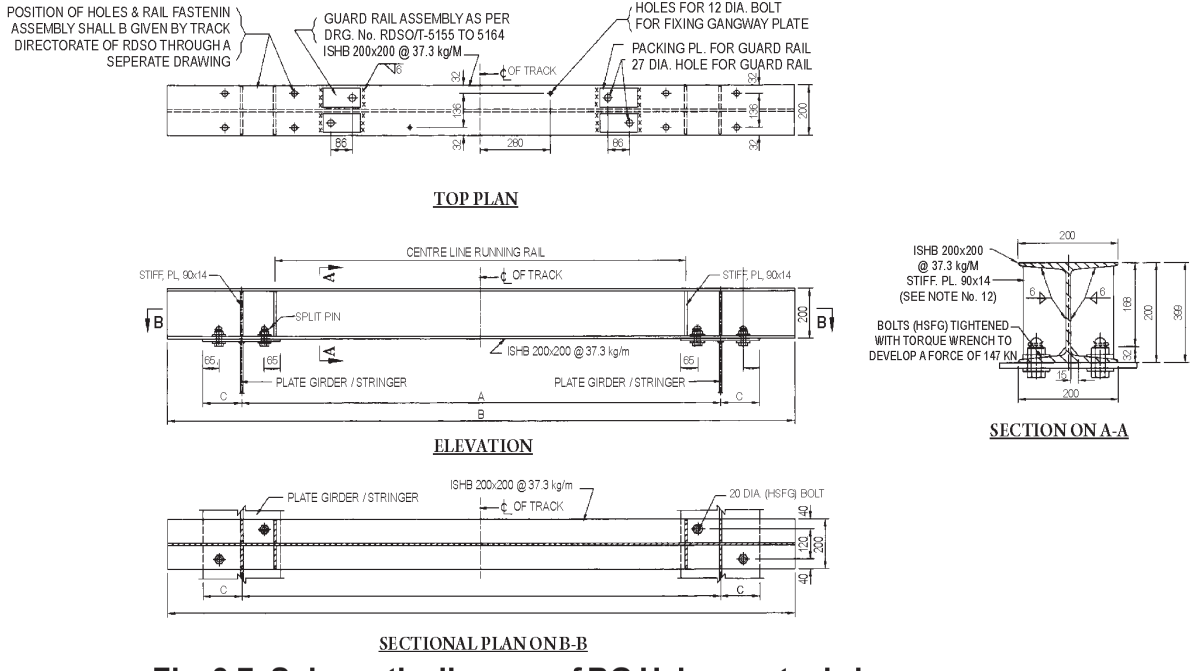


Fig. 3.7: Schemetic diagram of BG H- beam steel sleepers (For details refer RDSO/B-1636/8)

top flange of H-Beam for Rail Fastening Assembly shall be given by Track Directorate of RDSO through a separate drawing.

c) **Packing plates for fixing Guard Rails-** Two Nos. Packing plates are welded to the top flange of H-Beam as shown in the drawing for fixing Guard Rails for which 27 mm Dia. holes are drilled through in welded packing plates & H-Beam. Guard Rail Assembly will be as per Drg. No. RDSO / T-5155 to 5164.

d) **Gangway Plate-** In addition to above, 2 Nos. holes per sleeper placed diagonally for 12mm dia bolt for fixing Gangway Plate of size 6 x 740 mm are provided on top flange of H-Beam. This bolt and nut assembly includes split pin and Taper washer to suit to H-Beam top flange from bottom side. The arrangement for fixing gangway is shown in Fig 3.8.

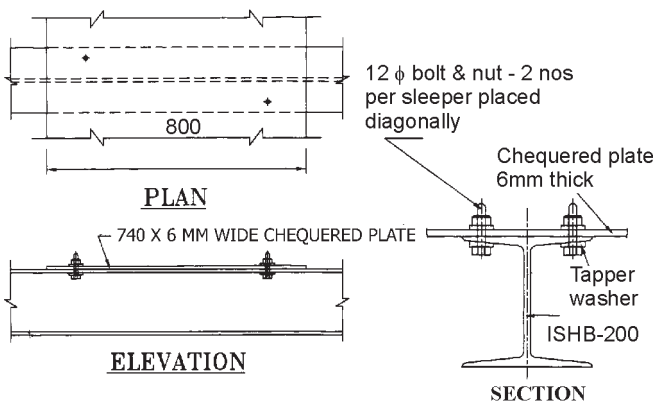


Fig. 3.8: Arrangement for fixing gangway, B.G. (RDSO/B-1636/8)

3.3.3 Track fittings for H-Beam sleepers

Base on an extensive exercise of detailed deliberations at RDSO developed Rail Free Fastening System. The rail free fastening requires simple arrangement in which the toe load of ERC is not transferred to the rail so that its longitudinal movement due to thermal forces is permitted but at the same time rail is secured in its position retaining desired line and level. RDSO Report No.CT-32 (Rev.1) detailed about Zero Toe Load Fastener (ZTLF) for which prototype to be developed and to be verified for the usability of the design in first phase. Field Trail of new design of Rail Free Fastening system is required for validation before adoption for regular use. The prototype should be fixed on H – Beam sleepers and offered for inspection to RDSO.

Field trial scheme for rail free fastening system on H-beam sleepers- Once prototype set is approved, the RFFS should be got developed by the firm and got them inspected by the consignee, with first 20% quantity by Track Directorate of RDSO, as per contract conditions. The performance of fittings shall be ascertained in actual field conditions through trial. The limited field trial shall be conducted initially for one year to cover changing weather conditions. Field trials shall be carried out under the direct supervision of the AEN of the section. Trains shall be permitted to run at restricted speed initially and speed may be raised subsequently.

Note: For details please refer RDSO Report No.CT – 32 (Rev.1).

The track fittings consist of the following components:

a) **SGCI bearing plate (SGBP) -** The SGCI bearing plate is to be manufactured as per drawing no. RDSO/T- 8392. The same plate can be used for both 60 Kg and 52 Kg rail sections. This bearing plate has been designed with insert similar to that used in PSC. The recess has been left in the middle portion of insert to house SGCI liner.

The SGBP material shall be same as that of SGCI inserts i.e. complying to IRS T-46. Bearing Plate shall be cast of SGCI conforming to the requirements of Grade SG 500/7 of IS: 1865-1991 "Iron Castings with spheroid or nodular graphite – specification" (Third Revision). General requirements relating to the supply of cast bearing plates shall conform to IS:1387-1967 "General Requirements for the Supply of Metallurgical Materials (First Revision).

At least 20% of initial quantity of given order during the trial period shall be inspected by Track Directorate of RDSO.

b) **SGCI Liner -** SGCI Liner is to be manufactured as per drawing no. RDSO/T- 8393 for 60 Kg rail and RDSO/T-8397 & 8398 for 52 Kg rail. These liners shall be placed in the recess formed in the ERC leg holding portion of insert on SGBP. Once the ERC is driven through hole provided in the insert, the leg of ERC shall pass through the SGCI liner. Once driven, toe of the ERC shall be supported on the SGCI liner while heel shall rest on the insert. The toe supporting portion of SGCI liner has been designed such that

the relative level of heel supporting portion of insert, hole in the insert to house ERC leg and top of the SGCI liner remain same as that in PSC Sleeper of RDSO Design. SGCI liner has been designed such that there is a gap of 2.5 mm between top of the flange of rail and bottom of the SGCI liner. This gap is required to allow free movement of rail in longitudinal direction. In case of overturning of rail due to lateral force, the end of rail flange shall come in contact with the bottom of liner and toe load of ERC over liner shall come in play to resist overturning. The same liner (Drawing No. RDSO/T-8393) shall be used on both gauge face and field (i.e. non-gauge face) side in case of 60 Kg rail. But there shall be separate liners for gauge face side (Drawing No. RDSO/T-8397) and for field side (Drawing No.RDSO/T-8398) for 52 kg rail.

The material for SGCI Liner shall be same as that of SGCI inserts. At least 20% of initial quantity of given order during the trial period shall be inspected by Track Directrorate of RDSO.

c) **Elastic Rail Clips Mk-III -** ERC Mk-III (Drg no. RDSO/T-3701) conforming to specification no. IRS-T-31-1992 with Corr.2 shall be used. Inspection is to be carried out by the nominated inspecting agency for the product for the zonal railway.

d) **Rail Pad -** 10 mm thick Composite GRSP (Drg no. RDSO/T-7010) conforming to specification RDSO/M&C/RP-200/2007 shall be placed over SGCI Canted Bearing Plate (SGCBP).

e) **HDPE Pad -** 2 mm thick HDPE Pad to Drg. No.

RDSO/T-8394 shall be placed below SGBP plate to provide a proper bearing of SGBP over H-beam. 2 mm thick HDPE Pad to Drg. No. RDSO/T-8394/1 shall be placed in between Rail and Rail pad to provide smooth surface for longitudinal movement of rail. HDPE pad shall be conforming to the IRS specification for Polyethylene Dowels for Concrete Sleepers (Provisional – 1997).

f) **Bolt with Lock Nut** - 25 mm dia special bolt to Drg. No. RDSO/T-8395 shall be used to fix SGCI Bearing Plate (SGBP) over H-Beam sleeper. This special bolt shall be provided with tapered washer to Drg No. RDSO/8353 at the bottom of top flange of H-Beam, plain washer over SGBP, spring washer in between plain washer and nut.The lock nut to Drg. No. RDSO/T- 8395/1 shall be provided after the nut has been fitted. The arrangement for providing split pin of 5 mm dia is also made above lock nut. The specification of plain washer, taper washer and single coil spring washer shall be as mentioned in IRS T-10.

g) **Fastening arrangement for Guard rail -** Guard rail fastening arrangement shall be similar to that given in Drg No. RDSO/T-5155 to 5164 on BG for 60 Kg running rail and 52 Kg guard rail and in Drg No. RDSO/T-5197 to 5200 for 52 Kg running rail and 52 Kg/90R guard rail. But the MS packing plate shall be of size 150 x 75 x 30 (in place of 150 x 75 x 22) as per drawing no. RDSO/T-8399. Tapered washer shall be provided as per drawing no. RDSO/T-8353 in place of RDSO/T- 5162.

Following table shows a comparative study of Track Fastening old and new ZTLF (Zero Toe Load Fastening) system for steel sleepers.

Table 3.3 Comparison of the new design of rail free fastening system of RDSO with ZTLF of old designs

SN.	Component		Comparison
	New Design of Rail Free Fastening System (RFFS)	**Available designs of ZTLF System**	
1	SGCI Bearing Plate	MS Canted Bearing Plate	SGCI plate shall be cast with insert with no/little machining required. SGCI plate shall be corrosion resistant compared to MS plate. No machining shall result in saving in cost.
2	SGCI Liner	MS/SGCI	Almost all design except Liner that of RDSO provides for separate liners for gauge face and non-gauge face side for 60 Kg rail. The new design shall use same liner for both the sides for 60 Kg rail reducing the inventory besides ease in application.
3	Bolt & Nut for fixing SGCI Bearing plate on H-Beam	Riveting for fixing MS Bearing plate on H-Beam	Bolt and Nut arrangement facilitate tightening and replacement in case of loosening and eventuality of damage. If rivet gets loosened or damaged, elaborate arrangement and time is required for replacement of existing rivets.
4	10 mm Composite GRSP to Drg No. RDSO/T-	10 mm GRSP of non-standard	10 mm CGRSP of standard size is being used in new design which can be procured from RDSO

Table Contd...

Table 3.3 Continued from previous page

SN.	Component		Comparison
	7010		size approved suppliers.
5	2 mm HDPE pad in between rail and rail pad	2 mm imbedded stainless steel (SS) plate in rubber pad	HDPE pad is used below rail to provide smooth surface for longitudinal movement of rail. Steel plate after roughness exerts higher friction.

3.4 HOOK BOLTS

Hook bolts are provided to outer edge of top flange plate on either side of girder to anchor the sleeper with the girder. Hook bolts are of two types :-

(1) **Straight lip -** Plate girder whether riveted or welded type requires straight lip hook bolts.

(2) **Tapered lip -** Stinger/rail bearer of through type open web girder requires taper lip to ensure full grip to rolled angle.

The diameter of the Hook Bolt shall be 28 mm and the length of the Hook Bolt shall be as per the requirement depending upon the site condition. Square portion of the Hook Bolt shall be long enough to go beyond rectangular hole of the bottom flange of Steel Sleepers so as to check the rotation of the Hook Bolt. The position of the bolt will vary from span to span. For 28 mm Ø bolt, hole of 32 mm Ø in top plate and square hole of 36 mm x 30 mm in bottom flange of steel sleepers are to be provided For each 28 mm Ø hook bolt, total 3 single coil spring washer as per IS:3063 shall be required. Split pin shall be of 4

mm Ø as per IS:549. There should not be any gap between split pin and nut of the bolt. In case any gap exists after tightening bolt, the gap should be filled by plain washers or shim of suitable thickness for effectiveness of the split pin. Nut dimension shall confirm to IS:1363.

3.5 FABRICATION OF STEEL SLEEPERS

Fabrication of steel sleeper is simple and required very simple infrastructure hence it can be fabricated in civil engineers workshop of zonal railways or by trade. Guide lines issued by RDSO for fabrication of steel channel sleepers vide Report No. 135-45 revised in May 2004 should be followed strictly for fabrication of these sleepers.

Steel sleeper is part of dynamic loaded track bridge and support the rail to transfer the load from rail to steel girder hence considering safety aspect, following precautions shall be taken during fabrication to avoid fatigue failure of weld or cracks in steel of HAZ (heat affected zone).

Table 3.4: RDSO drawings for different components of H-beam sleepers

S. No.	Title of Drawing	Drawing No.
1.	Rail Seat Assembly for Rail Free Fastening System for 60 Kg (UIC) Rail on H-Beam Steel Sleepers for Girder Bridge (BG)	RDSO/T-8391
2.	SGCI Bearing Plate for Rail Free Fastening System for 52 Kg/ 60 Kg (UIC) Rail on H Beam Steel Sleepers for Girder Bridge (BG)	RDSO/T-8392

Table Contd...

Table 3.4 Continued from previous page

S. No.	Title of Drawing	Drawing No.
3.	SGCI Special Liner for Rail Free Fastening System for 60 Kg (UIC) Rail on H Beam Steel Sleepers for Girder Bridge (BG)	RDSO/T-8393
4.	HDPE Pad for Rail Free Fastening System for 52 Kg/60 Kg (UIC) Rail on H Beam Steel Sleepers for Girder Bridges(BG)	RDSO/T-8394 & 8394/1
5.	25 mm Dia Special Bolt and Lock nut for Rail Free Fastening System for 52 Kg/60 Kg (UIC) Rail on H Beam Steel Sleepers for Girder Bridge (BG)	RDSO/T-8395 & 8395/1
6.	Rail Seat Assembly for Rail Free Fastening System for 52 Kg Rail on H-Beam Steel Sleepers for Girder Bridge(BG)	RDSO/T-8396
7.	SGCI Special Liner for Rail Free Fastening System for 52 Kg Rail on H Beam Steel Sleepers for Girder Bridge (BG)	RDSO/T-8397 & 8398
8.	30 mm thick packing plate for Rail Free Fastening System for Guard rail for H Beam Steel Sleepers for Girder Bridge (BG)	RDSO/T-8399
9.	M.S. Tapered Washer & Plain Washer for H-Beam Sleepers on Girder Bridge	RDSO/T-8353 & RDSO/T-8353/1
10.	Elastic Rail Clip Mk-III	RDSO/T-3701
11.	10 mm thick Composite Grooved Rubber Sole Plate	RDSO/T-7010
12.	6 mm thick Grooved Rubber Pad for Guard rail	RDSO/T-5163
13.	Bolt and Nut for Guard rail	RDSO/T-5164

3.5.1 Specification of steel for sleepers

Steel channel sleeper is critically loaded dynamic structure which directly supports rails of track on girders hence following steel shall be used:

a) Bridges located where service temperature does not fall below 0^0C, steel used shall confirm to IS-2062 grade 'B0' fully killed.

   Note: Till such time rolled channel not available of steel to IS - 2062 grade "B0" steel confirming to IS-2062 'A' fully killed can be used.

b) Bridges located in below sub zero temperature areas, steel shall be confirming to IS-2062 grade "C" fully killed.

Note: Steel used for fabrication should be tested one and must have mill test certificate clearly indicating the specification and fully killed. Fabricator should maintain the record of steel used with cast mark for verification if required at later date.

d) Rolled section should be within the rolling tolerances and surface defects prescribed in IS-1852.

3.5.2 Precautions

a) All steel section used in fabrication must have mill test certificate clearly indicating the steel specification conforming to IS-2062 grade “B0' or 'C', fully killed.

b) All steel plates and rolled section should be straight and free from twist before cutting for fabrication.

c) Oxy-acetylene gas cutting by mechanically controlled torch shall be used and cut edges to be ground. Profile of plate stiffener shall match with the profile of inner web and flange plate of both ISMC or ISHB for snug fit to avoid cracking of weld or root of ISMC or ISHB below rail seat.

d) Welding position shall be flat position (down hand welding) either by MMAW or CO_2 welding process as well as welding is carried out only by the qualified welders.

e) Electrodes shall confirm to IRS-M-28 of class A-2 or C-1 and wire for CO_2 welding shall confirm to specification of class-1 of IRS-M-46-2001. Preferably CO_2 welding shall be used for fabrication.

f) Welding procedures requires approval and testing as per Clause-19 of Welded Bridge Code and record of fabrication and test qualification shall be maintained in pro-forma as stipulated in Appendix-V of IRS serial B-1.

g) Before welding, all mill scale and dust adjoining weld face shall be removed and surface shall be cleaned and to avoid cracking of weld during service.

h) Bearing plates and supporting rails are connected to sleeper by rivet hence drilling of holes in sleeper after manufacture and in bearing plate shall be by drilling jig to ensure accuracy in rail gauge and alignment of rails on bridge. Rivets shall be driven with proper heating for the full length of shank to minimize loosening of rivets during service and reduce maintenance cost.

i) Fabrication of H-Beam Steel Sleepers which are

suitable for welded plate girders / stringers shall be done as per RDSO Specification BS: 45. Hot dip Galvanization to be done to the fabricated sleeper as per IS: 4759 to prevent corrosion. However CBE may permit use of the steel H-Beam sleeper with painting as per Para 218 of IRBM on economic and other practical grounds.

j) Entire surface of sleeper shall be grit blast cleaned before hot dip galvanizing as per IS-2629.

k) Zinc coating weight / thickness is most important factor from corrosion prevention point of view since sleeper is in vulnerable location and affected by disposal of passenger carriage and dropping chemicals and salts from goods wagon. Hence nominal coating weight 610 g/m^2 (85-86 µ tk) for long life of 15 to 20 years and 750 g/m^2 (105 µ tk) for severe corrosion location of bridge has to be ensured.

3.5.3 Inspection

To ensure minimum maintenance and safety of public, fabrication shall be in Civil Engineering Workshop of Zonal Railways or from trades who produce satisfactory evidence of his ability as stipulated in Clause-21 of Welded Bridge Code 2001.

Inspection shall be in accordance with Clause No.28, 29, 30, 31, 32 and 33 of Welded Bridge Code of 2001 so that cost of maintenance and repairs will be minimized.

3.6 ELASTOMERIC PAD

Elastomeric / rubber pad between bottom of steel channel sleeper and flange of girder, is essential to prevent cross bending of flange plate causing initiation of cracks in fillet weld or root of rolled angle under load. Sleepers are made up of steel, which is elastic material and cause cross bending under each axle passing. Elastomeric pad should be provided in case of stringer too. Thickness of elastomeric pad should be 25 mm or as stipulated in drawing.

3.7 FIXING OF STEEL CHANNEL SLEEPER ON STEEL GIRDERS

Arrangement of fixing of steel channel sleeper depends on type of steel girder, e.g. Plate Girder (Riveted/ Welded), Open Web through Steel Girder. In welded plate girder same thickness of top flange plate is provided through out the length of girder but flange width is different at mid-span than the end portions. Steel plate girders of span 12.2m, 18.3m & 24.4m span (either welded construction or riveted construction) are not provided with camber. Therefore a rail level on plate girder as well as on entire bridge has to be in one level. Whereas, open web steel girders are pre-stressed and fabricated with camber, so rail level on each span will coincide to camber profile of span. Sometimes splice plates are used for joining the flange plate and stringers irrespective of riveted or welded connection. To maintain desired level of track (i.e. uniform level for plate girders and cambered level for OWG) one has to calculate the thickness of steel packing plate at different locations. Accordingly the different thickness of packing plates and different size of sleepers are to be worked out on one span and same will be fabricated.

3.7.1 Fixing steel sleepers to riveted / welded plate girders / stringers

a) At the splice joints, additional M. S. Plates at top and bottom flanges of the girders are provided which are connected to each other with the help of rivets. Plate girders of standard spans are not having any camber as per Bridge Code. Therefore, a rail level on plate girders as well as on entire bridge has to be in one level.

b) For riveted / welded plate girder, suitable thickness of M.S. packing plate should be welded to the bottom flange of individual H-Beam of H-Beam sleeper to maintain the rail level due to thickness of splice plate and second plate (if provided).

c) The surface of the M.S. Plate to which the Elastomeric pad is to be bonded shall be cleaned to make it free from dirt, oil, grease, rust, mill-scale or any other extraneous matter. Holes of suitable dia. to be punched by pressure in the elastomeric pad for accommodation of rivet heads at splices and top lateral bracing connection with top flange of plate girder as per site condition.

d) To accommodate rivet heads at top flange, holes of 35mm dia. for 20mm dia. rivet shall be punched by pressure in the elastomeric pad whereas for 22 dia. rivet it should be 38mm dia. hole. So that steel sleeper does not rest on rivet head and to avoid rocking of sleeper under running of trains. These holes shall be filled with ready mix Zinc Crome priming paint conforming to IS: 2014 after placing the elastomeric pad in

position to avoid accumulation of water.

e) The adhesive shall be applied in thin layer uniformly spread both on the surface of the elastomeric pad and M.S. plate to be bonded. After application of adhesive 10 to 15 minutes shall be allowed before joining the two surfaces so as to allow the solvent to evaporate.

f) The surface of the elastomeric pad to be bonded shall be cleaned by gently rubbing with fine emery cloth for the purpose of removing any superficial layers of extraneous matter such as wax. Care shall be exercised during rubbing that the surface of the elastomeric pad is not damaged.

g) Elastomeric pad shall be joined to the top of the girder using Polychloroprene based self curing adhesive as provided in the RDSO drawings.

h) Elastomeric Pad shall be of the size 300mm x 25mm x 305mm. IRS Specification for 25mm thick Nylon Cord Reinforced Elastomeric Pad RDSO / M & C / RP-197 / 03.

i) Place the rail and fix it by rail fastening assembly as mentioned by Track Directorate of RDSO through a separate drawing.

Case study on failure of welded steel plate girder -

9.14 m span welded plate girders to RDSO Drg. No. B-1528 / 1, with riveted lateral bracings were manufactured at EWS / Arakkonam during 1993. These girders were

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Ref- Project Report by Mr. P. Sivaiah, AWM / EWS / Arakkonam / S. Rly., Mr. S. Mohan, AXEN / CS Ambattur / S. Rly. and Mr. Dharma Rao, AXEN / Floods / HQ / SC. Rly during Integrated course No.12102

erected during 1997. During the inspection of the girders by BRI in Dec - 2011, cracks were noticed in 3 girders (Span Nos. 1,3 & 5) over the web. The position of the crack was just below the top fillet weld in all the 3 girders invariably Fig 3.9 (a) & (b). The extent of cracks were ranging from 400 to 460 mm along the horizontal direction throughout the cross section of the web plate and visible on both sides.

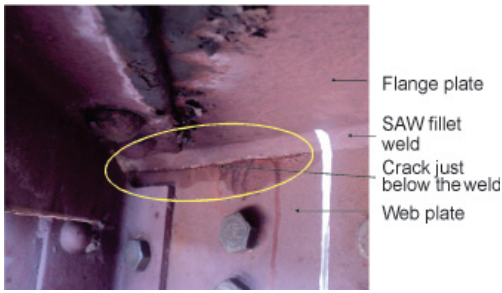


Fig. 3.9 (a) Crack below the top fillet weld inside the I-Section



Fig. 3.9 (b) Closer view of the crack

A team from EWS / Arakkonam investigated the failure and noted that . At the cracked locations the channel sleepers were found to be deformed and damaged Fig.3.10 (a) & (b)unevenly placed on flanges of plate girder. One end of the channel sleeper was seated properly on the top flange with rubber pad and another end was seated on the rivet head without providing groove to accommodate rivet heads resulting in non-uniform distribution of load Fig. 3.11 (a) & (b). The web plate was in the location under which the channel sleepers were placed on rivets. The extent of crack was proportional to the eccentricity of the channel sleeper with respect to the axis of the rivets, on which channel sleepers were placed.

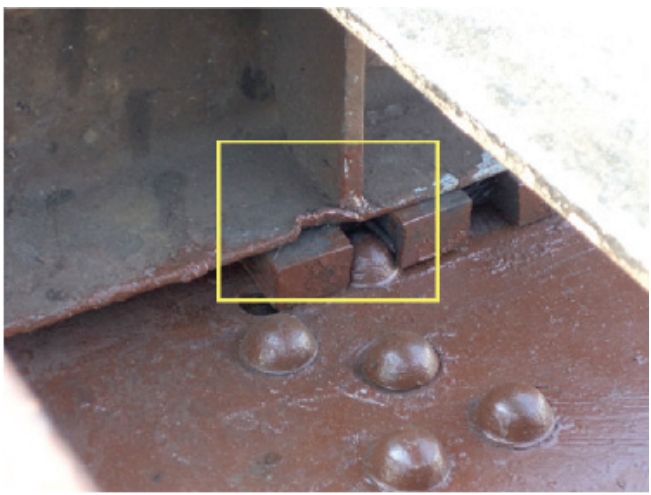
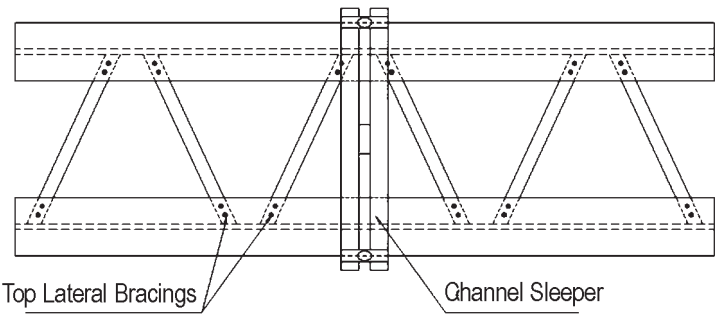


Fig. 3.10 (a) Bent bottom flange

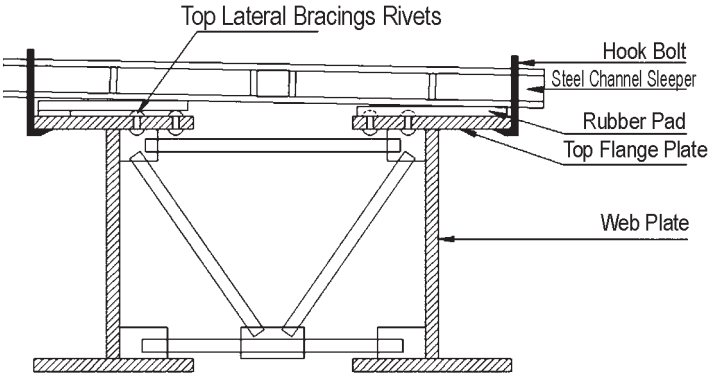


Fig. 3.10 (b) Torn bottom flange



Plan

Fig 3.11 (a) Wrong placement of channel sleeper on steel plate girder



Elevation

Fig 3.11 (b) Wrong placement of channel sleeper on steel plate girder

The cracked portion below the fillet weld were rectified, by grinding of the cracked area and site riveting. To prevent propagation of crack, 6 to 8 mm dia holes on either end of the crack were drilled. The web plate along the cracked locations was strengthened by providing additional stiffening angle (150 x 150 x 16 mm) with suitable packing plate (12 mm) on either side of the web plate duly connecting with the top flange plate, Fig. 3.12 Strengthening arrangement.

The Channel sleeper should never be rest directly on rivet head to avoid such failures.



Fig. 3.12 Strengthening arrangement

3.7.2 Fixing of steel sleepers to open web girder

As per steel bridge code all open web steel girder spans are to be fabricated with camber and pre-stressed. Therefore suitable thickness of steel packing plate with elastomeric pads to accommodate rivet heads is required so as to maintain the rail profile which will be similar to camber profile of span to ensure rail in level under the passage of train.

3.7.3 Precautions to be taken for while fixing of steel sleepers

a) Clean the top flange plate with wire brush and mark the sleeper position.

b) Steel channel sleepers can be for any type of girders, however, suitable section shall be

chosen depending upon requirement. The arrangement of fixing H-Beam with top flange of girder is suitable only when there are no rivets on top flange. Surface preparation and sleeper seat painting should be done while providing H-Beam sleeper on top flange.

c) Top flange portion and where (if exists) splice plate, additional flange plates and rivet heads of top lateral bracing system is there, steel sleepers to be laid with elastomeric pad and steel packing as mentioned above to accommodate rivet heads and ensure all are in one level.

d) Centre of sleeper should coincide with centre of span to ensure gauge face of alignment of rail.

e) After ensuring all sleepers are in the level and concentric to the span, sleepers to be anchored with the Hook bolt to girder on either side and nuts are tightened and level of the sleepers is checked to ensure it is in desired level.

f) Steel sleepers are available in different height i.e. channel sleepers of 150 mm and 175 mm height, H-Beam sleepers of 200 mm height. So depending upon the requirement suitable steel sleepers along with steel packing plate may be adopted. It is preferable to avoid mixing of different type of sleepers and different type of track fitting.

g) The level of the track shall be raised by 50 mm when H-Beam sleeper are provided as compared to the normal 150 mm high steel sleeper. The effect of such rise of track levels on Schedule of Dimension and existing Vertical Clearance on Electrified section shall be taken into consideration before actual laying for such sleepers.

h) For riveted / welded plate girders / stringers, where girders are having splice joints and there are rivets on the top flange. Fabrication of H-Beam Steel Sleeper and Galvanisation / Painting shall be done after fixing suitable packing plates. The H-Beam is anchored with Hook Bolt to the girder top flange on either side instead of HSFG Bolts for which the holes are drilled in H-Beam as shown in Drg. No. RDSO / B-1636 / 5.

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CHAPTER 4

INSPECTION OF STEEL GIRDER

4.0 INTRODUCTION

Bridge steel superstructure are expensive assets and involve heavy investment. Hence these must be managed well to give maximum service. Bridges should live their full designed life with minimum maintenance cost. To ensure this, a good bridge management system is essential to watch the bridge structure periodically during service. Inspection is a vital link in the chain of better management.

4.1 OBJECTIVES OF INSPECTION

The bridge inspection is done to ensure safety and serviceability. The purposes of inspection of a bridge can be identified as follows:

(a) to ensure that the bridge is structurally sound and safe and fit for its designed use. This relates to the gradual deterioration of the bridge with time or to an accidental occurrence such as impact or overloading.

(b) to identify actual and potential sources of trouble at the earliest possible stage.

(c) to record systematically and periodically the condition of the structure. This enables the

management to identify any significant structural changes and defects.

(d) to provide necessary information, on which decision can be taken for carrying out maintenance repairs, strengthening or replacement of the structure.

4.2 INSPECTION OF STEEL GIRDERS

The inspection of a bridge superstructure can be grouped into routine, detailed and special inspection. Chapter 11 of IRBM deals with inspection of bridges, which may be referred for details about bridge inspections conducted by various railway officials. Various inspections along with the frequency of inspection being done on Indian Railways are as follows:

a) Routine inspections

Inspections under this category are general in nature. Routine inspection are carried out most frequently and aimed at finding out obvious defects using simple inspection tools and procedures. These inspections are mostly visual inspection. In some cases simple observations like audible sound due to train movement or vibration felt while tapping the component of super structure may indicate presence of defect. This inspection also indicates whether detailed or special inspection is needed. These inspections are carried by an Asst. Engineer (vide Para 102 of IRBM) just after monsoon and by Supervisory officials before monsoon. The reason is obvious, i.e., to find out defects occurred due to monsoon and to insure soundness of structure before commencement of monsoon. Important bridges

are routinely inspected by Divisional. Engineers. Certain structures which are known to be having poor health due to any reason shall also be inspected by Bridge Inspecting officials at specified frequency; e.g., steel girders kept under observation, flooring system made of early steel, open web girders having progressive loss of camber.

b) Detail inspections

Detailed inspection are more detailed and carried out over longer time duration. Generally these are spread over uniformly over the time duration, e.g., 20% every year if entire structure is to be covered in 5 years. Depending upon span and the type of construction material suitable railway official are required to conduct the inspection. However, the levels of this inspection also not sophisticated. The Way/Work inspector are required to conduct inspection once in 5 year on pro-rata basis for super structure made of steel having clear span less than 12.2 m (vide Para 117 of IRBM). Bridge inspector is required to carry out inspection of steel girders having clear span more than or equal to 12.2 m (vide Para 107of IRBM). The nature of detailed inspection is such that it synchronises with the detailed maintenance of steel structures. This inspection is also aimed at finding out the requirement of further effort to maintain the structure.

c) Special inspection

Special inspections are in general outcome of routine or detail inspections. These inspections are also required for certain specified important bridges and due to unusual environmental or climatic conditions, e.g., highly corrosive environment, during unusual flood,

after derailments etc. Bridges having bridge rating poorer than that requiring routine maintenance (i.e., URN 1, 2 or 3) are inspected by Divnl. Engineers. Whenever bridges are referred by the field officials or otherwise requiring some remedial action, nominated DyCE., from headquarter may inspect such bridge in detail. This type of inspection is also needed while taking decision regarding retrofitting, rehabilitation or replacement of structure. The level of special inspection is somewhat sophisticated either due to higher exposure of inspecting officials or due to techniques involved in these inspections, i.e., non-destructive methods using sophisticated equipments to monitor health of the structure e.g. corrosion monitoring. Periodicity of health monitoring also depends on severity of environmental conditions. Whenever inspections are the basis of residual life assessment of superstructure, there instrumentation are to be planned. Other type of special inspection is during heavy rain and aimed at safe passage of trains.

4.2.1 Details of bridge inspections

The Detailed Inspection of a Bridge Includes Examination of :-

4.2.1.1. Girder alignment and seating

a) To ascertain whether

i. the position of girders in respect of line and level relative to the piers and abutments is correct,

ii. the bearings are fully and evenly seated on the

bed blocks and the holding down bolts are in position and anchored in the bed blocks,

iii. the rollers and the sliding plates provided at the expansion ends are well greased, free of dust and working freely to permit expansion and contraction.

iv. the date of lubrication of girder bearings is conspicuously painted,

v. the metal bearings are cracked or corroded,

vi. the elastomeric bearings are cracked or are showing signs of excessive deformation beyond the normal visible corrugations,

vii. the bearings provided with oil bath are covered free of dust and proper oil level is maintained.

b) Where possible, girders should be observed under train load for any abnormal movement or evidence of settlement. If a girder lifts off its bearings and "hammers" this must be specially reported.

4.2.1.2. Structural condition of girders

a) To ascertain whether the structural condition is satisfactory.

b) In triangulated spans, the following points should be observed :-

i. Loss of camber in the main girders assessed from comparative readings,

ii. Distortion of members,

iii. High incidence of loose rivets.

c) The following girder members should be examined for distortion:-

i. bottom chord members especially the unbraced sections near the ends of the span,

ii. top chord members with insufficient restraint by bracings,

iii. diagonal web members and tension members made up of flats,

iv. top flanges of plate girders.

d) To ascertain tightness of rivets by a sample test:-

i. Rust streaks close to rivets usually denote looseness,

ii. In the case of plate girders, loose and distorted rivets should be looked for at the connections of the main angles to the web plates below the sleepers and also at the ends of the girder.

iii. In triangulated spans field rivets should be examined at end connections of stringers to cross girders, cross girders connections to main girder, end connections of cross and lateral bracings, and chord joints and web member connections.

e) To ascertain whether inspection gangways have been provided on triangulated girder spans, where necessary.

f) In the case of welded girders, the girders shall be inspected over the entire length. Some of the weld details and critical locations, which should be given special attention during the inspection are:-

i. butt welds in tension flange or tension member,

ii. welds at ends of transverse and longitudinal stiffeners and welds of attachments to web and tension flange or tension member,

iii. ends of welded cover plates,

iv. intersecting weld,

v. locations having sudden change in cross section or configuration leading to stress concentrations,

vi. re-entrant corners and copes

vii. weld repairs and tack welds

viii. visible notches such as flame cut edges and mechanical indentations,

ix. splice joints,

x. bracing and cross frame connections with stiffeners,

xi. connections transmitting heavy torsion or in plane moments to members, i.e. stringer to cross girder and cross girder to main girder connections,

xii. ends of welds and weld craters,

xiii. unusual type connections,

xiv. bearings and their connections,

xv. members damaged or bent during transit, erection or in service,

xvi. structural details which are known to have exhibited fatigue problems on other bridges,

xvii. Locations having corrosion, pitting, etc. and loss of section.

g) In case of composite girders the junction between concrete slab and steel girder shall be inspected for:-

i. shear connector and girder connections,

ii. any vertical separation between girder and slab and also the critical locations mentioned in sub-para 2 (f) as applicable to the composite girder.

h) In the case of overstressed girders, the joints where the stresses in rivets in shear and bearing as per stress sheets are higher than the permissible working stresses should be examined.

4.2.1.3. The condition of steel work :

a) Action may be taken to ascertain whether the condition of paint is satisfactory and that no corrosion is taking place.

b) The following part of steel work which are prone to corrosion should be specially examined:-

i. where water is likely to collect or parts where alternate wetting and drying can take place,

ii. where longitudinal timbers are carried in

channel stringers and in the troughing of ballasted deck,

iii. steel work of girders and the underside of over bridges which are liable to corrosion by the action of fumes from engines and whether they are protected by smoke guards,

iv. around bearings of girders where debris can collect,

v. Inaccessible parts of structures like the inside of box girders with insufficient clearance between the flanges and behind bends of joggled stiffeners.

c) It is difficult to detect cracks in steel work as they are likely to be covered by a film of paint or corrosion and a careful inspection is necessary for their timely detection. Locations which must receive attention are:-

i. roots of flanges and angles where defects in rolling can initiate cracks,

ii. joints where heavy shear is transmitted,

iii. badly corroded members,

iv. bent plates, if shaped at an inadequate and low temperature and subjected to heavy and repeated dynamic loads.

d) Steel work in wrought iron or manufactured before 1905 (i.e. early steel) requires greater attention in regard to the existence of cracks.

e) Once cracks are detected, their likely cause should be investigated. If the investigations indicate certain deficiencies, girders of the same design and vintage must be closely

examined at corresponding locations.

4.2.2 Method of inspection

The inspection of bridge superstructure may be planned depending routine / general inspection, detail inspection or special inspection. The method employed for these inspections could be following:

(a) **Visual inspection -** This method grossly depends upon the visual inspection aided with simple measuring instruments and does not involve detailed technical observation. This method is suitable for routine or general inspection. Many times detailed technical inspection which are being done for each and every component of superstructure may also be carried out using simple unsophisticated instruments.

Visual inspections of various components of superstructure are dealt separately in forth coming para.

(b) **Non-destructive testing and instrumentation** - These methods are sophisticated method and demand highly skilled and trained man power. These method require sophisticated skill to interpret the data collected during testing etc. These method include non-destructive or partially destructive testing techniques. Many times simple NDT method may form a part of visual inspection if results are instantaneous and do not involve high skill. Instrumentation

of bridge superstructure require higher skill and calibre than most of NDT method. These methods are discussed in subsequent para.

4.2.3 Dye penetrant inspection during field inspection

Dye penetrant inspection is simple and low cost non destructive (NDT) inspection method for detecting minute discontinuities open to the surface such as fine cracks. Method is based on the ability of certain liquids to enter into fine cracks and crevices by capillary action and stay there when excess is removed. Hence this method may be used during regular inspection.

Equipment : Dye penetrant inspection kit consists of

- Dye penetrant
- Developer
- Cleaner
- Clean cloth or absorbent paper
- Penetrant and developer application equipment.

Dye penetrant inspection is carried out in followings steps:

i) Cleaning of surface to remove any dirt, rust or paint, etc. Surface should be thoroughly cleaned to enable dye penetrant to enter into the crack by cleaner.

ii) Application of dye penetrant to the area to be inspected. Dye penetrant may be applied by spraying or brushing.

iii) Allowing sufficient time for penetrant to enter

into the crack.

iv) Removal of excess dye penetrant -- Most excess is first wiped off with clean cloth or absorbent paper, followed by wiping with clean cloth or absorbent paper dampened with cleaner.

v) Application of developer, which is dry powder absorbent material, by dusting. Result is blotting action, which withdraws dye penetrant from the crack. Allow sufficient time for dye penetrant to blot on the developer. By chemical action white colour of developer turns to red if crack exists.

i) Examination of surface -- Crack is indicated by presence of red indications against white background of developer.

vii) Final cleaning after inspection.

4.2.4 Instrumentation of bridge super structure for running higher axle loads

Indian Railways has planned to carry out the instrumentation of bridges for health monitoring and capacity assessment. The selected bridge should be modeled using finite element method. Validation of finite element model is required to be done. The model is required to be validated for some boundary conditions. The Finite Element Model so developed shall be validated and updated with the help of experiment w.r.t. modal analysis, duly comparing the frequencies, mode shape, damping values, etc. Than the model is corrected with respect to experimental observations vis-à-vis capacity. Each bridge needs to be evaluated as an individual entity

regarding safety vis-à-vis its physical condition.

(a) Thorough physical inspection as per performa in bridge inspection register shall be done for each bridge, at the start of project.

(b) Any Bridges if found distressed, shall be sanctioned for rehabilitation immediately and execution to be taken up.

(c) Bridges shall be analyzed for the expected loading and wherever required, rehabilitation/strengthening be got sanctioned and taken up.

(d) The speed restrictions as required from safety consideration shall be imposed.

Bridge Instrumentation would broadly cover the following items.

(a) Stresses at critical locations.

(b) Deflections at critical locations.

(c) Dynamic augments.

(d) Longitudinal loads coming on bearings/ and substructures and proportion transferred to approaches.

(e) Tilting of abutments/ piers and stresses in the sub-structure.

(f) Fatigue analysis.

4.2.4.1 Location of strain gauges : Instrumentation required to cover the critical stresses and suggested locations for plate girder and open web girders are listed in Table - 4.1 and Table - 4.2

Table: 4.1 Instrumentation of plate girders

Critical stresses	Strain gauges location
The principal stresses Shear stresses	Rosette (0-45-90) on both sides of the end panel, at a distance of 0.7d from the ends, at the neutral axis on both girders.
Maximum compressive and tensile bending stresses	At the top and bottom chord at mid span for both the girders.
Estimation of the degree of fixity at the support (If satisfactory movement at bearing is observed, end plate strain gauges may be dispensed with).	Also at the top chord on both ends of one girder, at a distance of 0.7d from the ends each member being further mapped as having a strain gauge on the top of the top flange.
To ascertain cyclic stress pattern on cross girder. (If the condition of lateral cross girders is sound as per physical observation, then its instrumentation may be dispensed with).	On the lateral cross girders at top and bottom
Extent of out of plane bending (If the condition of lateral cross bracings is sound as per physical observation, then its instrumentation may be dispensed with).	On the lateral cross bracings at centre span

Table Contd...

Table : 4.1 Continued from previous page

Critical stresses	Strain gauges location
Stress distribution in the bearing.	In case of Centralized Bearing, rosette (0-45-90) on all four bearings of the test span. In case of Rocker-Roller, one bearing (Rocker) will be very comprehensively mapped with 4 to 6 electrical strain gauges on the stiffening spars. Electrical Strain gauge will be placed on the ridge of the two central stiffeners and two of the four end stiffeners.
The longitudinal force applied by the locomotives through drawbar. (If longitudinal force can be directly/indirectly measured at loco level, then above instrumentation can be dispensed with.)	Four strain gauges on four faces of the drawbar The data from these shall be recorded on the load cases of Full Motive Power and Brake Binding.

Table: 4.2 Instrumentation of open web girders

Critical stresses	Strain gauges location
Axial strain and moment, Estimation of the tractive effort	On the rocker end raker above the top flange and below the bottom flange on one truss and at the centroidal axis on the other truss. On the roller end raker, at the centroidal axis on both trusses.

Table Contd...

Table: 4.2 Continued from previous page

Critical stresses	Strain gauges location
	On the rocker side, first bottom chord, on top and centroidal axis of the other truss
Axial strain and moment	On the intermediate diagonal, at the rocker end, above the top flange and below the bottom flange on one truss, and on the centroidal axis on the other truss.
Axial strain and moment, out of plane moment and bending	On the bottom chord at mid-span at both top and bottom of one truss and on the centroidal axis of the other truss. On the top chord of the mid span member, at both top and bottom flange of one truss and on the centroidal axis of the other truss.
Stresses in the vertical posts	Two strain gauges will be placed on the centroidal axis of the vertical post, one on either truss on the rocker side.
To ascertain cyclic stress pattern on cross girder	On the lateral cross girders and rail bearer at two places, top and bottom flange at mid span.
Stress distribution in the bearing.	Both bearings (Rocker) will be very comprehensively mapped with 4 to 6 electrical strain gauges on the stiffening spars. Electrical

Table Contd...

Table : 4.2 Continued from previous page

Critical stresses	Strain gauges location
	Strain gauge will be placed on the ridge of the two central stiffeners and two of the four end stiffeners.
The longitudinal force applied by the locomotives through drawbar. (If longitudinal force can be directly/indirectly measured at loco level, then above instrumentation can be dispensed with.)	Four strain gauges on four aces of the drawbar. The data from these shall be recorded on the load cases of Full Motive Power and Brake Binding.

4.2.4.2 Frequency of instrumentation of bridges:-

The tentative frequencies may be as follows and in case CBE feels appropriate, the same can be changed suitably. The recording of data and analysis thereof would be required to be done for longer period so as to provide realistic data for future for allowing higher axle loads.

(a) **Stresses at critical locations -** Quarterly for one year and thereafter annually for three years. For new work it can be once for six months for one year and then yearly.

(b) **Deflections at critical locations** - Quarterly for one year and thereafter annually for three years. For new work it can be once for six months for one year and then yearly.

(c) **Longitudinal loads coming on bearings/ and substructures -** Quarterly for one year and hereafter annually for three years. For new work it can be once for six months for one year and then yearly.

(d) **Tilting of abutments/ piers and stresses in the sub-structure -** Quarterly for one year and thereafter annually for three years.

(e) **NDT tests for detection of any hidden defects/ cracks development -** Once in six months. For new works once a year for three years.

(f) **Load spectrum analysis including dynamic augment-** It shall require continuous record. These system may be got installed with recording over a quarter by agency and thereafter Railway personnel could get trained & take over recording.

4.3 ARRANGEMENT FOR INSPECTION OF BRIDGE SUPERSTRUCTURE

4.3.1 Equipments for inspection

The equipments require for inspection depends upon type and level of inspection. In-case of routine inspection these equipments are generally small, handy and easy to be used. In-case of detail inspection certain additional tools and simple NDT techniques like DPT may require. The equipments of special nature are needed for assessing cause of major defects and amount of residual fatigue life etc. or for rehabilitation / retrofitting of steel girder. The prescribe list of equipment for routine and detailed inspection are given in **Annexure 4.2.** The equipments for specified NDT method may be seen in IRICEN publication on NDT. Some of NDT equipments are listed in the following **Table - 4.3.** The instrumentation scheme are briefly touched but actual working experts in this field may be contacted.

Table - 4.3 NDT Methods of steel bridges -

S	Method	Used for	Equipments
1.	Dye-penetrating method	It is used to reveal surface breaking flaws by bleed out of a colored of fluorescent dye from the flaw.	Dye - penetrating equipment.
2.	Magnetic particle inspection (MPI)	To detect defects in the structures.	Magnetic particle inspection equipments.
3.	Eddy Current	Cracks, voids, Honey combing.	Eddy Current Meter
4.	Radiographic testing	It gives shadow image of an object or film by using penetrating radiation such as X-rays or Gamma rays.	Radiographic tester.
5.	Acoustic Emission technique	To measure the location and activity of cracks.	SPARTAN & MISTRAS System.
6.	Ultrasonic Flaw detector	To measure the location and size of grade	

4.3.2 Appurtenances for bridge inspection

Inspection of Bridge can be effective only if the inspection official is well equipped with support system that will lead him to various components of the bridge. The first requirement is to reach to the bridge site either by rail or by road; depending upon this the inspecting official has to plan for necessary arrangement for detailed

inspection of bridge. Once the inspecting official reaches the bridge site primarily he has two options – (i) either to reach the super structure from the ground below or (ii) he can directly reach to the super structure from top. Accordingly he has to plan for inspection of various components of super structure.

Common facilities for bridge inspection are discussed in detail in chapter three, include the chequered plate on the steel girder bridge (Fig.1.4) or path way on side of girder (Fig.1.5) for the keyman, scaffolding arrangement/ladders (Fig.1.6 & Fig.1.7) to reach top of through steel girder bridge, ladders to reach the bearing.

Many times permanent ladder arrangement is made to reach top of through girder bridges. Some Railways have attempted hanging cradle for PSC girder bridges (Fig.1.8). Beside these arrangements for inspection of bearing from all around of the pier and inspection of bottom chord/soffit of the bridge is also necessary.

However, these are make-shift arrangement predominantly temporary in nature and can be utilized as and when required. The biggest drawback of these arrangements is doubt about the safety and reliability of these non engineered structures as well as time required for erection of these arrangements.

4.3.3 Suitability of inspection arrangements

Suitability of inspection arrangements shall be decided after taking holistic view for each section based on various factors such as initial cost, labour requirement, ease of use, maintenance of arrangements, public nuisance/ security, feasibility, time taken for inspection/traffic block

and confidence of inspecting officials. The board recommendations for providing inspection arrangements can be as follows:

a) For bridges with low to moderate height temporary arrangement is sufficient
b) Bridges with abnormal height or inaccessible river bed may have permanent arrangements.
c) Sections where line block is a problem or numbers of bridges are large may have road inspection vehicle or permanent arrangements depending upon the economics.
d) If traffic blocks are easy but river bed is not accessible, rail mount inspection vehicle may be used.
e) If railway traffic is high and river bed is not accessible, permanent arrangements may be provided.
f) If bridge is provided with side pathway etc. for local public, the same may be suitably modified to facilitate bridge inspection.

These arrangements shall be planned in such a way that repair and routine maintenance activities could be easily performed. Transportation of the material and equipment to the site is shall also be considered at the time of planning for such arrangement.

4.3.4 Safety precautions

While inspecting bridges, one should adopt certain safety measures which are listed below:

1. Wear suitable dress so that loose ends do not

get caught; too-tight-a-dress may hamper your free movements.

2. If you normally wear glasses for improving your eye sight, wear them when climbing up or down the sub- structures or superstructures.
3. Keep clothing and shoes free of grease.
4. Scaffolding or platforms should be free from grease or other slippery substances.
5. Scaffolding and working platforms should be of adequate strength and must be secured against slipping or over turning.
6. Line block or power block shall be taken as and when necessary.
7. No short cuts, at any cost, should be adopted.

4.4 INSPECTION OF BEARINGS

One of the most important parts of a bridge is the bearing which transfers the forces coming from the superstructure to the substructure, allows for necessary movements and present unwanted movements of superstructure. Bearing could be of the following types

The bearings are required to be inspected at prescribed intervals. However, the bearings shall also be examined carefully after unusual occurrences, like movement of abnormal heavy traffic, earthquakes, cyclones and battering from debris in high floods. The inspection shall be preceded by careful cleaning of the bearings and its surrounding space, depending on the actual conditions around the bearings, e.g., deposit of salt, debris, dust or other foreign material. The results of every inspection to be recorded in the inspection report and shall be classified

in each case into the following types of action:

i. No action, further measurements long-term monitoring or design analysis needed

ii. Minor repair works e.g. cleaning, repainting etc.

iii. Repair or replacement of entire bearing or parts of the bearing.

iv. In case of defects for which the cause and necessary actions to be taken to set right the defects cannot be determined by the inspecting person or the responsible bridge engineer, the design engineers/ manufacturer should be consulted.

Table 4.4. Items to be inspected for different type of bearings

SN	Type of Bearing	Items to be inspected
1	Bearing : General for all type of Bearings	• Check whether the bearing is free to move / rotate in different directions as envisaged in design. • Check whether the bearings are fully a nd evenly seated. • Check whether the bearings are at same level. • Physical condition. • Cleanliness.
2	Metallic Bearings	• Rusting / Corrosion. • Unusual tilting of rollers. • Rollers jumping off the guides. • Condition of grease, when last greased/whether needs replacement. • Condition of anchor bolts, whether in position and not loose.

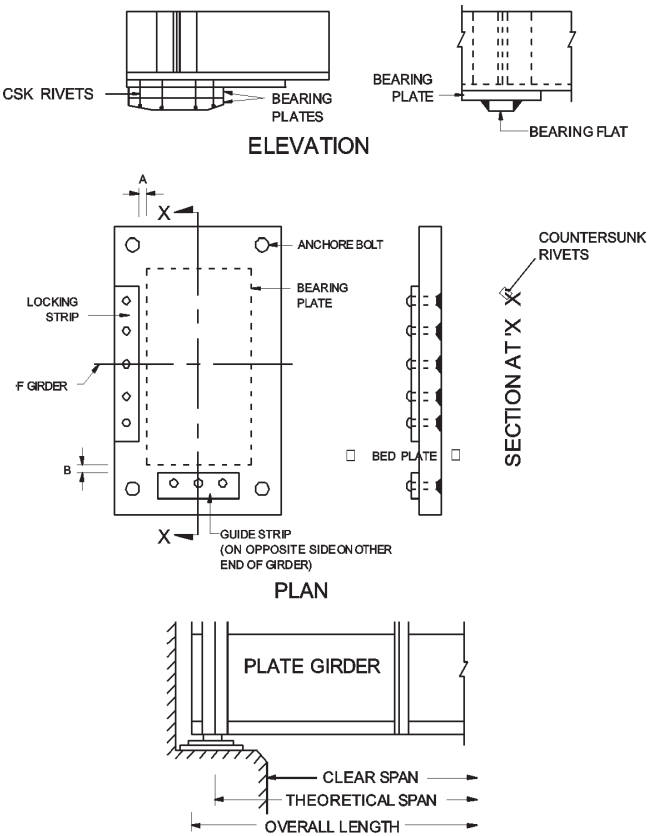
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SN	Type of Bearing	Items to be inspected
3	Elastomeric bearings	• Flattening. • Splitting / tearing • Bulging. • Oxidation. • Non uniform thickness other than that which may be the result of normal rotation. • Displacement (Longitudinal or Lateral) from original position.
4	Pot cum PTFE bearing	• Effectiveness of sealing lining whether elastomer is bulging out. • Whether PTFE is flowing out • Cracks at junction of pot and base plate. • Excessive movement of bearing. • Freezing and corrosion.

4.4.1 Inspection of centralized sliding bearings

In general sliding bearings shall be inspected and oiling and greasing is to be done once in three years. If bridge carries LWR, the sliding bearing shall be inspected during March and October every year and all foreign material are removed and bearings are cleaned. Excessive longitudinal movements of the superstructure result in shearing of location strips as well as anchor bolt connecting the base plates. Many times a uniform contact between the bottom face of the bed plate and top surface of the bed block is not ensured resulting in gap at certain locations. This leads to transfer of excessive impact forces to the bed block under live load. This may lead to cracking and crushing of bed block and masonry underneath. Therefore a sliding bearing should be inspected to cover all of the above aspects.



A - EXPANSION GAP 12 TO 20 mm

B - INSTALLATION GAP 1.5 TO 2 mm

NOTE: FOR ENSURING THESE GAPS, THE ANCHOR BOLTS SHOULD BE INSTALLED ACCURATELY IN PROPER POSITION.

Fig.4.1 Centralised sliding bearings

4.4.2 Inspection of Roller and rocker bearing -

Roller and Rocker bearing shall be inspected for several additional features besides those covered for sliding bearing. For example in case of segmental rollers, it should be seen that they are placed vertically at mean temperature, and the centreline of roller must coinsides with the centreline of the base plate. It is desirable that the completion drawings of bridges shall indicate the maximum designed expansion with the range of temperature (by indicating the maximum and minimum temperature), so that the slant at the time of greasing can be decided depending on the temperature at the time of greasing.

The rockers, pins and rollers should be free of corrosion and debris. Excessive corrosion may cause the bearing to "freeze" or lock and become incapable of movement. When movement of expansion bearings is inhibited, temperature forces can reach enormous values. The superstructure will be subjected to higher longitudinal forces. The tilt of segmental rollers should be measured with respect to reference line and the temperature at the time of measurement should also be noted. In case of roller bearings with oil baths, dust covers should invariably be provided to keep the oil free from dirt. The oil shall be replaced once in five years.

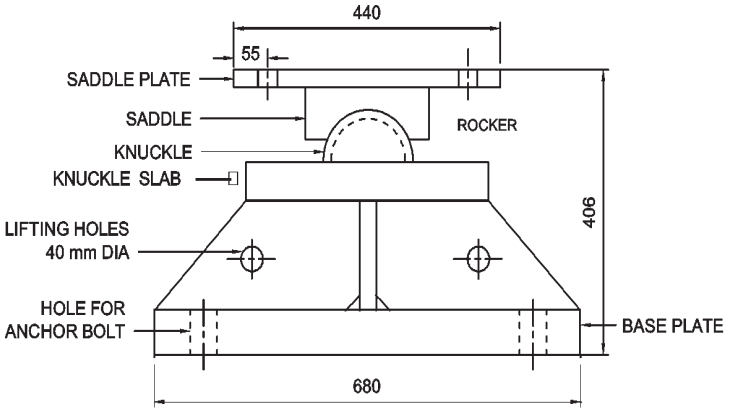


Fig. 4.2 (a) Roller and rocker bearing - Expansion Bearing - Roller end

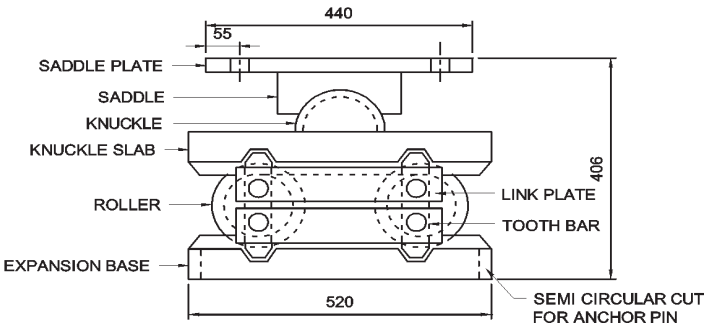


Fig. 4.2 (b) Roller and rocker bearing - Fixed Bearing - Rocker end

4.4.3 Inspection of Elastomeric bearings

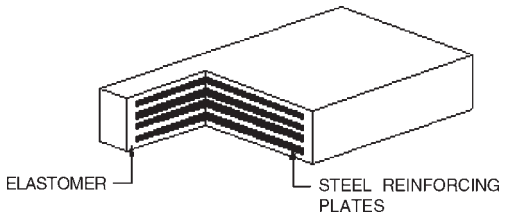


Fig. 4.3 Elastomeric laminated bearing

The greatest problem encountered with elastomeric bearings pertains to non conforming of the material to the specifications. Inferior quality product exhibit defects like cracking, splitting, bulging and tearing. The first sign of distress in elastomeric bearings is the onset of horizontal cracks near the junction of rubber pad and steel laminate. The bearings should also be examined for excessive rotation which is usually indicated by excessive difference in thickness between the back and the front of the bearing. The inspecting official should look for the following aspects:

- Correct position or placement of bearing.
- Excessive shear - Shear deformation should not be more than 50% of height of elastomeric pad.
- Excessive bulging.
- Separation of rubber from steel lamination.
- Cracking and tearing of elastomer.
- Flattening out or excessive compression should not be more than 5% of height of the pad.
- Excessive rotation – Rotation should not lead to off-loading of one edge.

4.4.4 Inspection of Pot-cum-PTFE bearings

Pot-cum-PTFE bearings have been used in important bridges like Third Godavari Bridge at Rajamundary (90 m span), Zuari and Mandori Bridges (120 m span) on the KRCL, Tansi Bridge (71.4 m + 102 m + 71.4 m span), Dudhar Bridge (64 m + 92 m + 64 m span) on Jammu Udhampur Rail link. Pot-cum-PTFE bearings are much thinner and permit large movement compared to roller bearings.

4.4.4.1 Common problem with Pot-cum-PTFE bearings

In Pot-cum-PTFE bearings, confined elastomeric pad is used to permit rotation under high compressive stress. Elastomeric pad behaves like a viscous fluid. There is tendency of leakage of elastomeric material if the sealing ring is ineffective. On the other hand if tolerance between metallic cylinder and pot is very light, the rotational capacity of the bearing is affected. In fact satisfactory rotational distribution could be achieved only when normal load more than 25% of bearing capacity is applied. Another problem is inability of steel pot to withstand the transverse loading. The PTFE element is also observed to flow out under heavy load.

At the time of placing the bearing temperature correction is necessarily to be applied and the expansion end of the bearing and the point of intersection shall match under full live load with impact. While fixing bearing care is taken for vibration and accidental impact, some anchorage should be provided and there should not be any voids below the bearings.

The bearings are required to be inspected at an interval of one year for the first five years and at an interval of two years thereafter. Followings are the elements to be inspected:

Measurement of movement - During inspection at site, measurements are required to be taken and documented to compute its movement and rotation values in relation to their design values to ascertain whether the performance of the bearings are satisfactory. To ascertain maximum movement, measurement should be taken once during peak winter (early morning) and once during peak summer (after noon) and corresponding atmospheric temperature should be recorded. The recoded value of movement shall be compared with the design values.

Measurement of dimensions - Overall dimensions of the bearings is required to be measured and compared with the actual dimensions to ascertain any excessive stress or strain on the bearing.

Evidence of lock in condition - If any moveable or rotating part of a bearing is found to be in locked-in/ jammed condition, necessary rectification measures shall be taken immediately.

Evidence of corrosion - If corrosion of any part of exterior exposed steel surface of the bearing is detected then the affected portion shall be cleaned using wire brush and protective coating shall be applied, as specified by the manufacturer.

Condition of the adjacent bridge structure - The adjacent structure of the bearings are also required to be

inspected for any damage and necessary actions to repair the same, should be initiated. The root cause of defect should be searched and remedial actions should be planned to avoid recurrence of the problem.

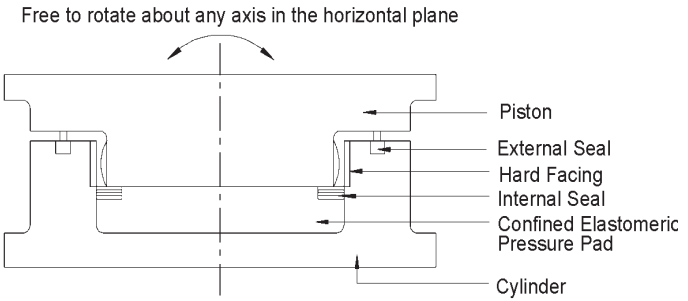


Fig. 4.4 (a) Schematic diagram of Pot-cum PTFE bearing (Fixed end)

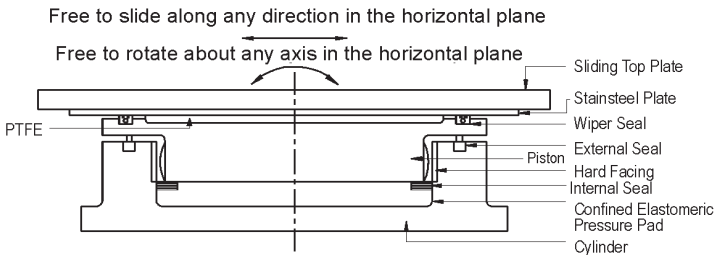


Fig. 4.4(b) Schematic diagram of Pot-cum PTFE bearing (Free End)

4.5 INSPECTION OF STEEL GIRDER

Foot Over Bridge - Truss type Foot over bridge girders are fabricated as cambered girder (unprestressed). Camber recorded at centre of span during inspection should be compared with the initial dead load camber as recorded in the Camber Register and camber recorded

during the last inspection to detect any loss of dead load camber in steel truss or sagging of plate girder. In foot over bridge truss type girder, camber is to be recorded at midpoint of truss and compared with dead load camber in register as well as camber recorded during last inspection to ascertain any loss of camber.

Plate girder - All standard plate girders are of less than 35 m span, hence camber is not provided. In plate girders, levels have to be recorded on top flange plate to ascertain that there is no sagging of girder when recorded levels are compared with last inspection recorded levels.

Open web girders - All open web girders of railway track bridges are provided with camber and are pre-stressed. Dead load camber (recorded after assembly and erection) should be retained during the service life of girder if there is no distress. Therefore, during technical inspection, first, camber is checked at permanent location at every panel point of both truss with the help of dumpy level or precision level, which will facilitate the inspection officials to understand the structural condition. As far as possible camber observations are required to be taken at the ambient temperature mentioned in the stress sheet.

In open web through span girders, camber is to be recorded at every panel point of bottom chords of both trusses of span and compared with dead load camber in register as well as camber recorded during last inspection to ascertain any loss of camber. In open web deck type (underslung) girder camber is to be recorded at every panel point of top chords of both trusses of span and compared with dead load camber in register as well as camber recorded during last inspection to ascertain any loss of camber. Good practice is 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.

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 has taken place and structure is not distressed.

4.5.1 Loss of camber

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

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

If any loss of camber is noticed during inspection, as a first step, 30 kmph speed restriction is to be imposed and following investigation is to be carried out:

1. Girder should be thoroughly inspected to establish the cause by critically checking for loose rivets at panel joints or at splices. Also all members should be thoroughly inspected

for distortion or deformation.

2. Stress reading of critical members under maximum load should also be taken either by Faraday Palmer Stress Recorder or strain gauge methods to check if any member is over-stressed. Check whether bearings are frozen.

3. After investigation, speed restriction should be relaxed with the approval of Chief Bridge Engineer. Loss of camber and other details of investigation report should be recorded in bridge register for future guidance.

4. Based on the investigation, proposal should be made to replace all the loose rivets of panel joints, with oversize rivets or for strengthening of members with the approval of Chief Bridge Engineer as a special work.

4.5.2 Distortion

In plate girders following members are likely to show distortion:

i) Top flange plate being a member carrying compressive stresses.

ii) Web plate near the bearings due to heavy concentration of stress.

iii) Cross frame angles and top lateral bracing angles due to excessive lateral vibration

In open web girders the following members are likely to show distortion.

i) Top chord members carrying compressive stresses if not sufficiently restrained.

ii) Diagonal web members particularly if they are made up of flats and most likely at mid-span due to stress reversal and vibration during passage of train.

iii) Bottom chord members which carry tension and longitudinal forces if not properly braced. The most likely location is near the bearings in case of frozen bearings.

iv) Top lateral and portal bracings are likely to distort due to excessive lateral forces.

Distortion is also possible when longitudinal rnovement of girders due to temperature variation is arrested on account of frozen bearings.

Sometimes web member i.e. diagonal, vertical and end rakers in through girder bridges are hit by moving loads due to shifting of load in wagons, particularly overdimensioned consignment (ODC). Hence, these members should be checked at 1.2 meters above rail level for any damage.

Distortion can be checked visually as well as by a piano wire stretched between panel points over the members or by special distance gauges.

If distortion is noticed, cause of distortion is to be ascertained. First, if it is due to frozen bearing, corrective measure should be taken immediately to restore the mobility of bearings. Further, strengthening the members as well as providing lateral restraint by providing additional

lacings, battens and diaphragms should be contemplated. If lateral bracings and cross frame of plate girders are showing signs of distortion, they should be replaced by higher section angles.

4.5.3 Corrosion

Steel structures are sensitive to the atmospheric conditions such as humidity, acidic gases and presence of salt. It is one of the major factors causing considerable corrosion to steel work. Corrosion eats up the steel section and reduces its structural capacity, which if not arrested in time, will cause heavy repairs to strength the structure and ultimately will lead to replacement of the girder.

Hence it is an important item of inspection, to keep maintenance expenditure minimum. A paint film is provided over steel work as an inhibitor of corrosion. With the passage of time, due to extreme heat and cold or abrasions by sleepers or due to stagnation of water, this protective paint film starts scaling off and gradually exposes the original steel surface to the atmosphere.

There are certain locations in girders, which are more prone to corrosion than the other areas. These are as follows:

1. Where the top flange is coming in contact with sleeper Fig. 4.5
2. Formation of water pockets on account of construction features.
3. Places where dust can accumulate.
4. The presence of moisture near drainage

system, particularly with concrete deck composite girders, road over bridge girder, etc.

5. Locations where water repeatedly comes in contact with steel structure.



Fig. 4.5 Where top flange comes in contact with sleeper

Once the corrosion sets in the top flange plate it advances and spoils the rivet connection with cross bracings, vertical stiffeners etc. Fig.4.6 (a) & (b).



Fig. 4.6 (a) Rivet connection with cross bracing & stiffeners.



Fig. 4.6 (b) Rivet connection with cross bracing & stiffeners.

Presence of moisture aggravates corrosion. Therefore, proper drainage on structures such as troughed decks or boxes formed at panel points of through girders or concrete decks must be ensured. On girders provided

with steel trough/ concrete decks and ballasted track, deep screening of ballast is rarely carried out. This results in blocking of drainage holes and impounding of water. Further, such situation leads to seepage of water through troughs and concrete decks, finally resulting in corrosion of top flange and reinforcement.



Fig. 4.7 Corrosion of bracings connected with top boom

Special attention should be paid to the following locations.

1. Sleeper seats.
2. Flooring arrangement and connection with bottom chords, cross girders, rail bearers.
3. Gusset connection of top lateral bracing to top boom.
4. Inside fabricated boxes of bottom boom.
5. Area in the vicinity of bearings.
6. Trough of ballasted decks.
7. Underside of road over bridges.

8. Seating of wooden floors on FOBs and floor beam and main girder connection in case of CC Paving.
9. Interface between steel and concrete in composite girder.
10. Parts of bridge girders exposed to sea breeze and salt water spray.

Therefore, special attention should be given during inspection to the portions of steel work where corrosion is likely to be more prevalent. Such locations are:

1. Sleeper seats - Top flanges of plate girders and underslung girders or top flanges of rail bearers (stringers) in through spans.
2. Steel affected by fumes of diesel loco like web members of truss of through girder.
3. Water pockets due to construction features - open web span bottom chord panel points form pockets for stagnation of rainwater, flooring arrangement and connection with bottom chords, cross girders, rail bearers and in plate girders behind bent stiffeners.
4. Steel work in the vicinity of bearings.
5. Troughing of ballasted deck.
6. Top lateral bracings and portal bracings of through spans.
7. Parts of the bridge steel work exposed to sea breeze and salt water spray.
8. Interface between steel and concrete in composite girder and ROB girder.

9. Underside of road over bridges and web plates near road deck level of ROB semi through girder.

10. Base of columns, seating of wooden floor in FOBs as well as staircase steps.

It is important to assess the magnitude of corrosion and consequent loss of effective structural section and also to identify the cause of corrosion. Members and connections subject to high stress fluctuations and stress reversals in service are the most common suspect in respect of corrosion. Due to corrosion, loss of cross sectional area takes place, which may leads to development of cracks (Fig. 4.8)



Fig. 4.8. Crack and corrosion at sleeper seat

Railway bridge girder painting consists of minimum (a) primer coat (b) cover coat. Therefore, first paint film to scale is cover coat. Hence only cover coat is repainted with patch painting in certain locations which will prove to be economical as surface preparation for cover coat

painting is rather than unnecessarily scaling down the good and compact base coat which will increase the cost of painting as well as wastage of paint. Therefore, the inspecting officials should clearly indicate the following during inspection:

i) Major portion of steel work requires cover coat painting and at some locations patch painting.

ii) Steel girder requires complete painting.

iii) Only patch painting.

iv) Paint in good condition, hence no painting is required.

This will help in planning for painting, preparation of tender schedule and providing funds for maintenance painting. It is needless to say that bridge steel girder's economical service life is mainly dictated by proper inspection and maintenance painting.

4.5.4 Early steel girders

There are a number of steel girders on Indian Railways fabricated before 1895. During those early times, the steel manufacturing technology was not fully developed and steel manufactured in those times contained excessive phosphorous. Concepts of quality control were apparently vague and steel used in the different parts of even the same bridge was found to have varying content of phosphorous. Higher phosphorous content makes the steel brittle and such girders can collapse suddenly because of brittle fracture. So, it is necessary to ascertain the chemical composition of

steel. Therefore, it is necessary to conduct detailed examination of such steel girders at an increased frequency with a careful and critical eye. Many times residual life assessment is also carried out for fatigue point of view. Even steel which was manufactured between 1895 and 1905 should be treated as 'suspect' and inspected at an increased frequency.

4.5.5 Fatigue cracks

Fatigue is the tendency of metal to fail at lower stress level when subjected to cyclic loading than when subjected to static loading. Fatigue failures are more common where stress concentration due to sharp corners and abrupt change of cross section exist. In case of Open Web Girder different member has different stress level and frequency of loading. Influence line diagram provide sufficient clues to this. Tendency of every development of crack and its progress may be linked to it.

Fatigue is becoming important because of growing volume of traffic at greater speeds and higher axle loads.

Fatigue failure in the form of cracking of steel section is a major cause in Railway track bridges on account of repeated stresses. Cracking because of repeated stresses is one of the major causes of potential failures in steel structures. Cracking in an angle diagonal of the truss usually starts from a rivet or bolt nearest to the edge of the member. The crack then progresses to the edge of the leg and continues through the other leg to complete the failure. Fatigue cracking is found usually where the local stress is high such as at connections or

at changes in geometry. (Fig. 4.9). One should look for such fatigue cracks where the intensity of traffic is heavy and the steel is old.

Following are critical locations of cracking:

i) Ends of diagonal members near middle of the span due to reversal of stresses.

ii) Sharp edges at cut notch in stringer flanges at connections with cross girders.

iii) Top flange plates or flange angles of plate girders or rail bearers especially below the sleepers.

iv) Top flange plates or flange angles of plate girders or rail bearers especially below the sleepers.

v) Roots of channel and angles on account of rolling defects.

v) Corrosion pits at any location in tension member. Joints where heavy shear is transmitted.



Fig. 4.9 Development of crack at riveted connection due to excessive vibration

Assessment of Residual fatigue life

The essential information which is required to assess the fatique life of a structure is the pattern of stresses likely to be observed in it, during the passage of normal traffic and the relationship between the applied stress cycles and the number of times these can be withstood by the member detail or connection of the structure. Such S-N relationships are usually available in various codes of practices for different type of connections. Under normal service conditions, Railway bridge structures are subjected to spectrum of varying stress-amplitude and therefore, a process of damage accumulation continues. The fatique damage depends on the combined effect of the frequencies of different stress ranges observed by the structure under service loading.

The residual fatigue life of an individual member detail or

connection thus is governed by the stress range spectrum causing fatique damage and the capacity of the member detail or connection to absorb fatique effects. The stress range spectrum primarily depends on the loading intensities, their sequences and the structural configuration inwhich the member detail or connections are placed. In the present case the arrangement is based on the revised fatique provision of IRS Steel Bridge Code and then the design life of the steel girders. The residual fatique life is thereafter calculated by deducting the service life already obtained.

To arrest the crack propagation, a hole should be drilled at the end of the crack in plate and cover material is provided with rivets. The usual inspection for the detection of fatigue cracking are done with magnifying glass or tapping rivet testing hammer to detect by metallic sound. It is very easy to detect cracks during scraping for full painting of girder.

4.5.5.1 Action to be taken when a crack is detected or suspected during inspection.

Following action should be taken on detection of a crack or suspected crack:

i) Location should be marked distinctly with paint as an easy indication for reference and subsequent inspection. Ends of crack should also be accurately marked to monitor crack propagation.

ii) Length and orientation of crack should be recorded. Sketch should be prepared

indicating the location and details of crack. If necessary photographs may be taken.

iii) If necessary, crack should be examined in detail using non-destructive testing methods like Ultrasonic (USFD) test to know the depth of crack.

iv) If more identical details exist on the girder. these should also be inspected in detail.

v) Significance and severity of crack should be studied with reference to the load carrying capacity of the girder.

vi) The crack and girder should be kept under observation depending on the severity of crack and frequency of inspection suitably increased.

vii) If a crack is suspected at any location, paint film should be removed and detailed examination carried out using magnifying glass or dye penetrant testing or ultrasonic testing as necessary.

viii) Crack should be fully documented in the bridge inspection register and action initiated for its early repairs.

ix) Repair or retrofit scheme should be prepared after fully investigating the cause of the crack and implemented at the earliest. Repair or retrofit scheme must have the approval of Chief Bridge Engineer.

4.5.5.2 Repair of crack (temporary)

The method of repair of crack should be decided based on the location and severity of damage due to the crack but temporary measure to arrest the further growth of crack is to be taken first.

a) If the crack in a component is propagating in a direction perpendicular to the stress in a member, 22.0 mm dia hole may be drilled at crack ends to arrest the crack propagation. The edge of holes should be placed at visible ends of the crack. After the holes are drilled it should be checked that crack tips have been removed and do not pass through the hole. After checking the hole, high tensile bolts or turned bolt of 22 mm dia should be provided in the hole and fully tightened. This will generally be temporary repair. Any reduction in strength of girder due to the crack and drilling of holes should be given due consideration.

b) If crack is in a fillet weld connecting web to flange (top or bottom) clamp is to be provided as temporary measure to arrest further growth of crack.

c) If crack is in fillet weld of stiffener, temporary wooden stiffener is to be provided by the side of stiffener to arrest the growth of crack.

d) If crack is in butt weld of flange plates, either side cover plate with 10% increased thickness is to be provided and clamping to be done with U clamps as temporary measure to arrest the growth of crack.

e) Record in Inspection note and Bridge Register:

The observations during inspection should be recorded in detail in the bridge inspection register for each crack in welded girder.

i) Details of cracks, i.e. size, location, orientation, crack propagation details, etc. should be recorded in the bridge register.

ii) Full details of temporary repairs measures undertaken for the cracks should also be recorded in the bridge inspection register.

f) For permanent repair, member may be retrofitted with riveted or bolted splice or else replacement of member should be done. Fig.4.10 shows a typical detail of a retrofit bolted splice for repair of crack at welded cover plate end.

g) Field welding should not be undertaken for repair of cracks except under the specific approval of Chief Bridge Engineer for cracks of minor significance and with full precautions, using electrodes of appropriate class to IRS / M-28 specification and weld repair proved free of defects by non-destructive inspection.

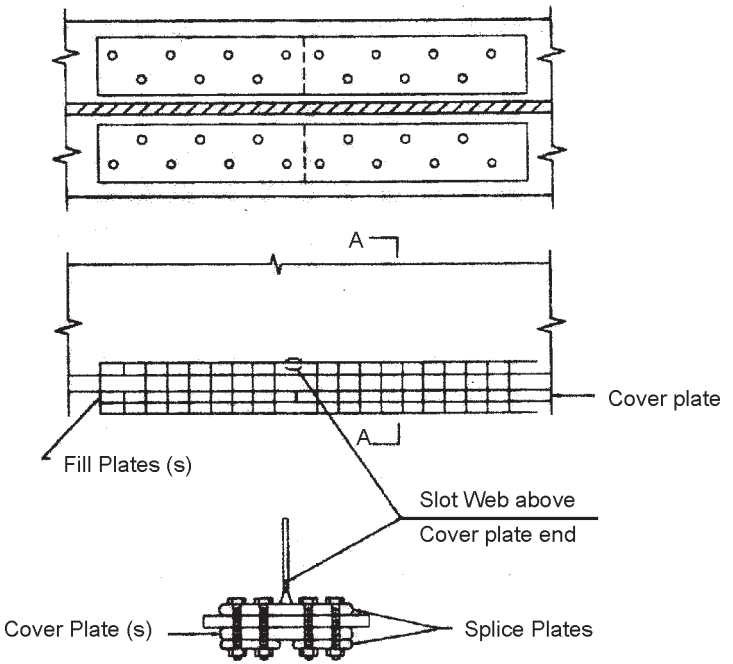


Fig. 4.10 Typical details of a retrofit bolted splice

4.6. INSPECTION OF RIVETTED CONNECTION

4.6.1 Loose rivets

It is experienced in the past that no loose rivets are noticed in steel girders of foot over-bridges and road over bridges. Rivets may get loose only when girders have outlived their design life or overstressed. Fig. 4.11 shows loose rivets in connection of a diaphragm with I girders of a shallow type girder. Rivets of steel girder of track bridges tend to become loose after 40 to 50 years of service life.

Rivets which are driven at site and rivets which are subjected to heavy vibrations are prone to become loose. Corrosion around rivets also causes their loosening. If rivets were not driven properly during fabrication and erection there these have to be replaced even earlier than normal stipulated life as above.

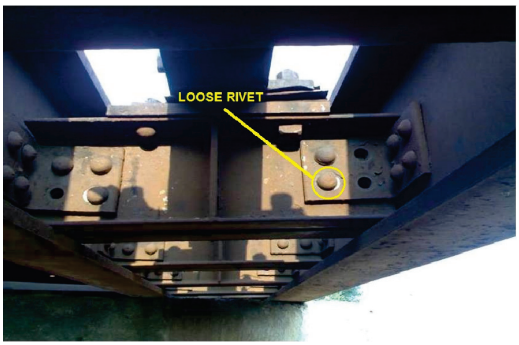


Fig. 4.11 Loose rivets in connection of a diaphragm with I girders

The rivets in steel girders of track bridges fall in the following 3 groups:

a) First group called as stitch rivets are driven to form a member. These rivets are driven in workshop and mostly do not become loose in service life of girder upto 80 to 100 years. 75% of total rivets in steel girders fall in this category. (Diameter of rivets is 20mm and hole diameter is 21.5mm).

b) Second group are rivets at joints connecting members. These are also called as field rivets. These rivets transfer the load from member to joint. They are driven at site with hand-driven pneumatic hammer and tend to

become loose after 40 to 50 years. (Diameter of rivets is 22mm and hole is 23.5mm). All joints are provided with 10% extra rivets in design stage. The rivets which transfer load from component to component are very important for checking.

c) Third group of rivets connect top and bottom lateral bracings including sway and portal bracings. These rivets tend to become loose on account of vibrations. If found loose they should be replaced.

The present practice in some of the zonal railways is to test all the rivets falling in above 3 groups in steel girders during 5 years technical inspection, carried out by SE/JE Bridges. It is observed that testing of rivets by rivet hammer chips off the paint film, making rivet head steel exposed to environment leading to corrosion of rivet heads. During technical inspection rivets shall be inspected at critical location, for detail, please refer Chapter XI of Bridge Manual. This will reduce the rivet testing work of bridge branch and reduction of cost in maintenance on account of reduction in replacement of corroded head rivets. When girders are old and certification of higher speeds of existing girders is required, all rivets shall be tested before the full painting of girders so that corrosion of rivet head is avoided.

Critical locations for testing loose rivets are as follows:

a) In plate girder/composite girder:

   i) Rivets connecting web plate to flange angle of top and bottom flanges particularly at the ends of girder i.e. upto 1/12 of span

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Ref: Report No.BS-90 for details

from either end support and below the sleepers for top flange plate.

ii) Bearing stiffener rivets.

iii) Splice rivets of flanges.

iv) Bracing and cross-frame connections.

b) For open web girders:

i) Rivets connecting rail bearers (stringers) to cross girders in case of through span.

ii) Rivets connecting cross girder to panel point gussets.

iii) Rivets connection at all panel points with main gussets to truss components of top chord and bottom chord (field connections).

iv) Rivets connecting bottom lateral bracings to end cross girders as well as top lateral bracings and portal bracings.

Note: Rivets listed in item (i) and (ii) of open web girders are subjected to direct shear and sometimes induce tension due to excessive deflection of rail bearers and cross girders. Hence loose rivets noticed in these joints should be replaced to avoid overstressing of other rivets or shearing of rivet heads.

Careful observation should be made to detect loose rivet at joints riveted in field and decision should be taken for replacement. If there are only one or two slightly finger loose rivets at staggered location or less than 10% in a particular connection, it should be allowed to remain under

observation with white paint mark for identification. If more rivets are loose at one location, they should be replaced to avoid overstressing of other rivets. This needs careful understanding and good experience and discretion.

Rivets connecting to Secondary members such as bracings, are prone to become loose on account of vibrations and are required for replacement when found loose even though the strength of plate girder or truss is not affected directly.

Many times rivets are replaced on account of corroded heads. This is because of bad maintenance practices and not due to structural defects. Rivets should be replaced only with pneumatic hand driven rivet hammer which works at compressed air pressure of 6.5 to 7.6 kg/ crn2. No hand riveting is permitted on main member of steel girder.

Maintaining proper record of loose rivets in group 2 & 3, particularly of open web girder, will help in assessing structural condition in future inspection. Therefore, proforma shown in Fig. 4.12 may be used for proper record. One form will be required for each span. This will build the history of girder and help the ADEN for Numerical Rating during his annual inspection.

LOOSE RIVETS IN TRUSS MEMBERS

BOTT. PANEL		L0			L1				L2						L3					L4						L5					L6						L7			L8		
No. of FR		ER	BC	XG	BC	V	BC	XG	BC	D	V	D	BC	XG	BC	V	BC	XG	BC	D	V	D	BC	XG	BC	V	BC	XG	BC	D	V	D	BC	XG	BC	V	BC	XG	ER	BC	XG
R	IN SIDE																																									
G	OUT SIDE																																									
L	IN SIDE																																									
G	OUT SIDE																																									

TOP PANEL		U1					U2			U3					U4			U5					U6			U7				
No. of FR		ER	P	V	D	TC	TC	V	TC	TC	D	V	D	TC	TC	V	TC	TC	D	V	D	TC	TC	V	TC	TC	D	V	P	ER
R	IN SIDE																													
G	OUT SIDE																													
L	IN SIDE																													
G	OUT SIDE																													

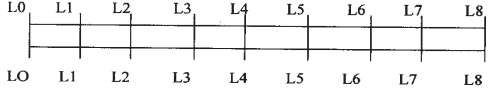
RAIL BEARER TO CROSS GIRDER

		L0	L1	L2	L3	L4	L5	L6	L7	L8
RG	IN									
	OUT									
LG	IN									
	OUT									

CAMBER GIRDER

	LO	L1	L2	L3	L4	L5	L6	L7	L8	
RG										LAST READING
										PRESENT READING
										LOSS
LG										LAST READING
										PRESENT READING
										LOSS

FLOOR SYSTEM



REFERENCES

ER= END RAKER
BR= BOTTOM CHORD
XG = CROSS GIRDER
LG = LEFT GIRDER
FR = FIELD RIVET
TC = TOP CHORD
RG= RIGHT GIRDER
LG = LEFT GIRDER
FR = FIELD RIVET
P = PORTAL

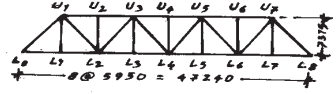


Fig. No.4.1 Recording of Loose Rivets

Fig. 4.12 Record keeping of loose rivets

4.6.2 Testing of loose rivets

Rivets which are driven at site and rivets which are subjected to heavy vibrations like bracings, foot-path, trolley refuge etc. are prone to become loose. Corrosion around the rivet will indicate the looseness of rivet. Due to vibration of loose rivet, paint film gets broken and corrosion sets in. To test rivets at any critical locations mentioned above or sample testing, both hands are required to be free. Therefore, proper staging is essential. Left hand index finger is placed on one side of rivet head duly touching rivet and steel member as shown in Fig. 4.13. Then strike the rivet head on the opposite side with a rivet testing hammer weighing 110 gms with 300 mm long handle. If the rivet is loose, vibration movement is felt by the left hand index finger. This requires a little experience. The loose rivets are marked with white paint and entered in loose rivets proforma. Depending upon number of loose rivets and their location it will be programmed for replacement or kept under observation.

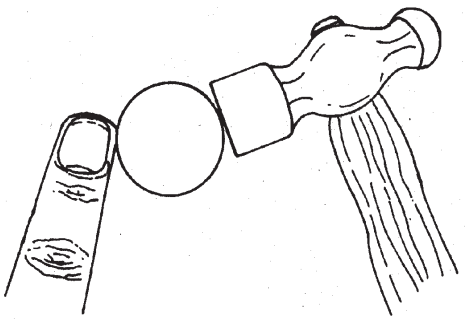


Fig. 4.13 Testing rivet for looseness

Testing for loose rivets by this method is not allowed for the girders which are painted with long life painting scheme such as metalized (aluminum), so as not to cause

mechanical damage to the coating layer. The loose rivet in that case has to be identified by rust streaks or other such indirect means.

4.7 INSPECTION OF WELDED CONNECTION

All welds carried out in workshop are by submerged arc welding (SAW) which is a fully automatic process and produces sound weld. Only at some locations where SAW is not feasible welding is done by manual metal arc welding (MMAW) or Co_2 welding. All railway workshops have trained staff and all fabricated girders are inspected by RDSO before despatch from workshop to ensure quality control and economical service life.

Plate girders are provided with centralised articulated bearings and composite girders are provided with Bronze bearings.

4.7.1 Method of inspection

All items like recording of levels of top flange to detect any sag, corrosion of steel, condition of paint, excessive deflection, distortion of any member, condition of bearings, testing of riveted connection of bracings and splices (if any), track structure on bridges, are similar to those of riveted girders including damage due to external hitting during erection. These should be thoroughly checked.

All welds should be inspected visually to detect any crack in the weld or heat affected zone of parent metal. Any crack will show sign of corrosion around it (as the paint film is broken along the crack). Visual inspection includes

using powerful magnifying glass. Mirror may be used to reflect the light on the particular location.

The following locations are to be observed especially to detect cracks during inspection:

(1) All butt joints in flange plates, particularly tension flanges.

(2) All discontinuities of weld edges such as ends of girders, adjoining cope holes in web, intermediate stiffener bottom ends of fillet welds near tension flange.

(3) Welds near the rivetted splice joints

(4) Intersecting welds (crossing one weld over the other weld)

(5) Any locations where weld repairs are already done during fabrication.

(6) In composite girders, any crack in top flange near shear connectors or cracks in adjoining concrete slab.

(7) In composite girders any vertical separation of top flange of girder and slab.

For above locations, in addition to visual inspection, non destructive tests like dye-penetration test, or magnetic particle examination test should be used to locate any fine crack in surface which cannot be detected by visual inspection. For hidden crack in and around weld USFD may be adopted, particularly web flange connection and butt weld in web and flange.

Fig. 4.14 & 4.15 (a) & (b) show cracks found at end of stiffener and in the flooring system of open web girder respectively. Inspection proforma will be the same as that prescribed in IRBM and a sketch or photograph indicating the location of crack as well as length and width of crack may be enclosed.

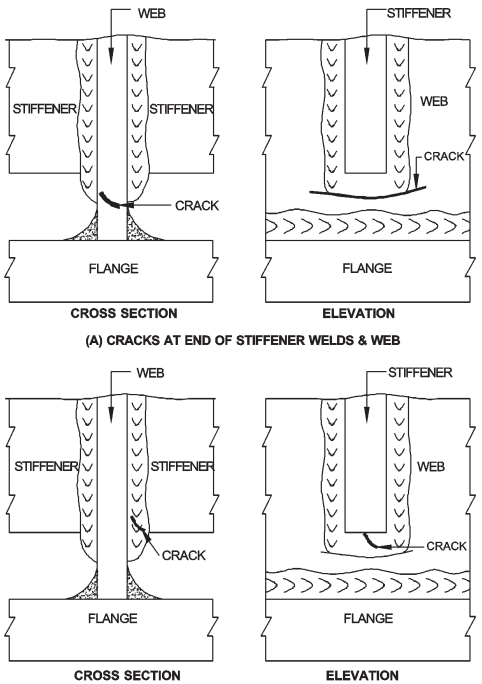
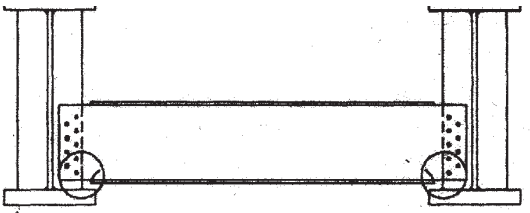


Fig. 4.14 Cracks found at ends of stiffeners

Fig. 4.15 (a) Cracks in the floor system of open web girder



Diaphragm having coped flanges showing likely crack location

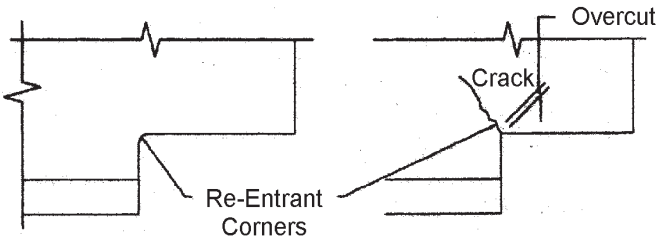


Fig. 4.15 (b) Diaphragm having coped flanges showing likely crack location

4.8 INSPECTION OF HSFG BOLTS

The inspection of High Strength Friction Grip (HSFG) bolts shall be done visually for broken and loose bolts. Hitting HSFG bolts for checking looseness is not allowed. The broken/loose bolts, if any, shall be marked and shall be replaced expeditiously by new HSFG bolts, retightening of loose bolts are not allowed in any case. HSFG bolts shall be painted as per normal painting schedules and painting methodologies. For detail inspection method please refer para 2.7 ante.

Note: When any girder component/joint is to be replaced, the complete joint shall have HSFG bolts. HSFG bolts cannot be used for replacement of isolated loose rivets.

4.9 CASE STUDIES ON INSPECTION AND REPAIR OF STEEL GIRDER BRIDGES

4.9.1 Case study of probable cause of cracks in different members and assignment of residual fatique life of bridge No.46 Up / mid line near Bilaspur, SECR.

Main problem is fatigue life i.e. whether residual life of the bridge is available or not? RDSO investigated about residual life of bridge No.46 Up and Mid line.

These bridges were instrumented to asses the level of stresses near the locations of cracks in different members of the bridge. This will be helpful in finding out the probable cause of cracks. Simultaneously Residual life of the girders of the bridge can also be estimated by instrumentation of different members at critical locations. Following observations are made:

i) Observed value of stresses measured on different members are well below the permissible limit. Design review has been done and theoretically no over stress has been found.

ii) Among the various bridge components, Diagonal is having the minimum residual life and estimated to 226 years with respect to present day loading intensity. As such, as a whole, residual life of the bridge with present day loading is 226 years.

iii) The above residual life is for on an average 57 trains per day for up line girders. If number of trains increase / decrease in future, residual life can be decrease / increase on prorata basis.

These bridges consisting 10x30.5 m + 2 x 12.2 m span is located at km. 668 / 3-17 between Champa - Naila section of Bilaspur division of SECR. Under slung girders of these bridges were manufactured in the year1966. Cracks were noticed during inspection between November-05 to July-07 in different spans of both the bridges. Up line girders are having more cracks than Mid line girders. Since Feb' 06 CC+8+2 loading was introduces in this section. However, the defects were noticed well before introduction of CC+8+2. After introduction of higher axle load the defects did not increased further till such time repair work taken into hand. The cracks have been designated as A, B & C as described below:-

1. Crack 'A' - Crack at bending portion of bent plate connected with end raker and top chord over bearing. (Fig.4.16)



Fig. 4.16 Crack type 'A' on bending portion of bent plate

2. Crack 'B' - Crack at bending portion of top bend plate connected with end raker to bottom chord. (Fig 4.17)



Fig. 4.17 Crack type ‘B’ on bending portion of bent plate

3. Crack 'C' - Crack at web area between web-flange junction and inside channel of top chord near end of girder over bearing area. (Fig.4.18)



Fig. 4.18 Crack type ‘C’ on channel of top chord after strengthening

Above mentioned cracks 'A' and 'B' were repaired by replacing the bent plates at locations of cracks, while cracks 'C' were repaired by strengthening the inside

channel of top chord. After repair no cracks were observed.

In view of the above, action required to be taken by the Railway for underslung girders designed to RDSO drawing No.B-6081 are as follows:-

i) The bridge should be kept under close observation.

ii) Wherever cracks have been observed, a small dia. hole (5 to 6 mm dia.) is to be driven on both ends of the cracks to arrest their further increase in length.

iii) Cracked bent plate should be replaced with new bent plate of 10 to 12 mm thickness.

iv) Seating arrangement of channel sleeper with top chord is required to be provided as per RDSO Drawing No.BA-1636 / 1 / R2.

v) Whenever cracks have been noticed in web of inner channel of Top chord on bearing area they should be strengthened.

vi) While doing the routine inspection of the bridge girders, a comparatively more attention should be paid on diagonal, bottom chord members and joints to have fair observations. Based on that RDSO will further review its decision for betterment.

4.9.2 Case study on assessment of residual fatique life of bridge No. 586 near KORAPUT, ECo Railway.

Bridge No.586 (3 x 18.3 m span plate girder) is situated at

km.198 / 9-11 on K K line section of E.Co. Rly., Bhuvneshwar. The above bridge was built for BGML loading in the year 1960 as per superstructure drawing No. BA – 1057. The track is laid with 60 kg rail with SWR and having 3 degree curvature. The gradient is 1 in 100 rising in loaded direction. Instrumentation of the bridges was undertaken by B&S Directorate of RDSO under the running traffic during Dec., 2008.

Maximum stress range is taken as the difference of maximum stress likely to come in the member with DL, Impact load & live load and the dead load stress. The maximum bending stresses due to equivalent uniformly distributed load for IRS loadings given in Bridge Rules, have been worked out and the maximum stress range is calculated for the sectional speeds 75 kmph and 60 kmph. As per the calculations for design BGML loading and CDA formula presently being used, the maximum stress range at 60 kmph is calculated to be as 98.4 MPa.

As a first step the assessment of design fatique life has been made based on the above stress range (98.4 MPa) calculated at 60 kmph. The design fatique life comes out as 12 years. Since the bridge has already given a service life of 50 years, this estimate of design fatique life is over conservative and needed revision. Hence, the experimental data obtained through instrumentation has been utilized to improve the estimate of residual fatique life.

During the field instrumentation a maximum stress range of 70 MPa has been observed in the top flange (bending compression). However, the fatique is not considered critical in compression and therefore, the maximum stress range of 60 MPa observed in the bottom flange (bending tension), is considered to govern the estimate of design

fatique. As per this total life is estimated to be 133 years out of which 50 years are completed so residual fatique life is 83 years.

The results of analysis may be interpreted keeping in view the following:

i) Assessment is based on average GMT of the route over the life span of the bridge. The GMT being carried in present may be actually different.

ii) It is to be noted that the annual GMT for a particular route may not be comprised of the trains causing maximum stress range. Situation may vary route wise and partial GMT may be due to trains causing much lower stress range. Therefore fatique life assessment is on conservative side.

iii) In cases the fatique life assessed is less than the service life of the bridge and there are no fatique cracks reported, a more detailed fatique assessment would be required taking into consideration the representative traffic load model consisting of actual set of trains on the route.

iv) It is assumed that the physical condition of the bridge is otherwise sound from other considerations and there is no adverse effect of corrosion, pitting and other defects during the service life of the bridge.

Annexure 4.1

Inspection proforma of steel girder (track bridge)

(1) Name of the Inspector .....

(2) Date of Inspection .....

(3) Section .....

(4) ADEN's Sub-Division .....

(5) Kms / TP .....

(6) Bridge No. .....

(7) Name of the Bridge .....

(8) Between Stations .....

(9) No. of spans .....

(10) Clear span square/skew .....

(11) Effective span .....

(12) Over all length of span .....

(13) Whether bridge is skew or on curve .....

(14) Speed restriction if any and its reason .....

(15) Type of girder .....

(16) No. of girders per span .....

(17) No. of tracks on bridge .....

(18) Standard of loading .....

(19) When put into road .....

(20) When strengthened/ regirdered and Drg. No. .....

(21) Drg. No. for steel work in girders .....

(22) Type of steel .....

(23) Camber of span .....

(a) As per Camber register .....

(b) At the time of last inspection .....

(c) At the time of present inspection .....

(d) Method of measurement .....

(24) Loss of Camber of each span .....
at the time of inspection .....

(25) The clear height between Road/Rail level to bottom most member of girder (for RUB & flyover) .....

(a) Actual .....

(b) Minimum required .....

(c) Infringement .....

(26) Type and condition of piers and abutment .....

(27) Type and size of bed blocks .....

(28) Condition of bed blocks .....

(29) Type of bearing .....

(30) No. of anchor bolts on each bed plates .....

(31) Condition of anchor bolts .....

(32) Type of pads below bed plate .....

(33) No. of trolly refuges on bridge and how many required .....

(a) Infringement if any after placing the trolly .....

(b) No. of man refugee on bridge. And how many required .....

(c) Footpath provided on which side Up/DOWN/Both sides/Not at all .....

(34) Defective Rivets

Locations	Cracked	Loose	Corroded	Total Nos.
(a) Boom/flanges				
(b) Web member/web				
(c) Main joints				
(d) Cross girders				
(e) Stringers				
(f) Bracings & Foot-path				

(g) Base plate .....

(For details see proforma of loose rivets)

(35) Damage of members of span such as buckling, crack, distortion etc .....

(36) Date of last painting (a) Complete (b) Patch

(37) Condition of paint .....

(38) Date of cleaning and greasing of bearings and present condition .....

(39) Condition of cylinders / trestles .....

(40) Movement of girders (if any) .....

(41) Condition of bridge .....

(42) General remarks .....

(43) Classification of defects into those requiring action by .....

(a) SE/JE Bridges .....

(b) Division .....

(c) Dy.CE (Bridge) .....

Railway

No. Date Office of SE/JE Bridge

Copy forwarded to :

(1) Dy.CE,(Bridge) .....

(2) Sr.DEN/DEN .....

(3) SEN/ADEN .....

(4) SE/JE P. Way .....

(5) SE/JE Work .....

SE/JE Bridges Signature

Annexure 4.2

Tools and Equipment for Inspection of Bridge

SN	Tool / Equipment	Purpose	Required For *
1	2	3	4
1	Rivet testing hammer (110g)	For testing looseness of rivets	A, B, C, D, E
2	Inspection cum chipping hammer	For checking hollow pocket/ honeycomb in masonry and concrete structure including PSC by tapping and for examining the extent of corrosion, adherence of paint on girders, and for removing loose scales	A, B, C
3	Elcometer (coating thickness gauge)	For measuring thickness of paint, metalised coating, etc.	A or B
4	Pocket steel tape (3m)	For measuring gap between girders or between girder and abutment, dimension of steel members, size of cracks, etc.	A, B, C,
5	Straight edge (1 m)	For checking deformation/ distortion/ buckling of steel components, bulge of masonry structure, etc.	A, B, C,
6	Metallic tape (30m)	For taking measurements such as clear span, overall length of girders, etc.	A, B, C, D, E
7	Log line with 20 kg. lead ball	For measuring scour depth, lifting/ lowering of tools and tackles for examination purpose, etc.	B (as required)
8	Probing rod	For checking firmness of ground and scour measurements	B
9	Calliper (inside)	For measuring the thickness of steel sections, dia. of solid/	A, B, C,
10	Calliper (outside)	hollow pipes, dia. of rivets/ bolts/holes, etc.	A, B, C,
11	Set of feeler gauges (0.1 to 5mm)	For measuring the width of fine cracks and cavity between parts or adjacent components	A, B, C,

Table Contd...

Table continued from previous page

SN	Tool / Equipment	Purpose	Required For *
1	2	3	4
12	Mirror (10 x 15 cm)	For inspecting parts in any awkward location by reflection method and to lit objects in dark location by directing Sun rays to facilitate inspection	A, B, C,
13	Torch light (5 cell)	Used alongwith mirror for identification of fine cracks in dark location; for safe passage through tunnels and other dark areas, etc.	A, B, C,
14	Magnifying glass (100 mm dia.)	For identifying very fine cracks in members/welds which may not be visible with naked eyes	A, B, C,
15	Piano wire with Clamps and 2 Nos. 10 kg. weight	For measuring camber in PSC girders, etc.	A
16	Plumb bob	For checking verticality of girder member/ pier abutment/trestles, etc.	A, B, C,
17	Chisel	For removing unwanted hard deposits like concrete, etc. for inspection/maintenance purposes	A
18	Steel scrapper	For scrapping rust/dirt/ paint for inspection, for pretreatment to dye penetration tests of welds, etc.	A
19	Thermometer	For recording temperature at the time of measuring camber, for the purpose of setting of bearings at the desired position.	A
20	Spirit level	For checking gauge and cross level of track on bridges or at bridge approaches, for proper setting of girders on bearinqs, etc.	A
21	Binoculars	For inspection of bridge components which are at inaccessible location, tall	D

Table Contd...

Table continued from previous page

SN	Tool / Equipment	Purpose	Required For *
1	2	3	4
		piers, arches in viaducts, etc. prior to closer examination.	
22	Current meter	For measuring velocity of water	D, E
23	Echo sounder	For measuring depth of water, for assessment of scour	E
24	Schmidt's concrete testing hammer	For assessing the strength of concrete structure by NDT method	D, E
25	Concrete cover meter	For assessing the cover available to reinforcement in existing RCC structures bv NDT method	E
26	Dial gauge	For measurement of deflections in case like load testing of arch/ steel / PSC bridqes, etc.	E
27	Dye penetration kit	For inspection of welded bridges	E
28	Magnetic crack detector		
29	Welding gauges		
30	Helmet	For safety of the inspecting officials	A
31	Safety belt		
32	Fibre glass boat **	To facilitate access to bridge structure located in water, etc.	B

* The following notations have been adopted regarding supply of gadget / equipments :

A - BRI	B - PWI	C - AEN
D - Divisional Hd. Qrs.		E - Zonal railway Hd. Qrs.

** Only for officials who have bridges with large waterways requiring the use of boats to be decided by CBE.

■ ■ ■

CHAPTER 5

MAINTENANCE OF STEEL GIRDER

5.0 INTRODUCTION

Steel is a good structural material and steel superstructures are strong, sturdy and time tested for more than 100 years on Indian Railways. But if steel girders are not properly provided with protective painting this results in setting of heavy corrosion to members, causing reduction of life, uneconomical strengthening and sometimes leading to replacement of superstructure. The adages "Prevention is better than cure" and "A stitch in time saves nine" are eminently true for steel superstructure. Considering all these aspects, it is essential for the maintenance engineers to provide planned and systematic maintenance during service life of steel girders. Inspection of bridges is a part of maintenance work. The periodical maintenance and repairs based on the inspection delivers more benefit and prove economical in long run to prolong the steel superstructure's life. Indian Railways had adopted systematic routine inspection and maintenance of bridge structures.

Adoption of higher loading standard and increase in speed of train results in increase in traffic density, this often increases maintenance activities. Besides these the ever increasing track maintenance and increase in

number of bridges due to new lines, maintenance of bridges needs to be more systematic.

5.1 MAIN ITEMS OF MAINTENANCE OF STEEL SUPERSTRUCTURE

a) Inspection and recording
b) Cleaning and greasing of bearings
c) Protective painting system to steel structure
d) Replacement of loose rivets or repairs to welds
e) Strengthening of steel superstructure
f) Replacement of corroded rivets.

5.1.1 Foot over bridges

Steel girders used for foot over bridges are statically loaded structures. No bearing is provided and hence the prime maintenance required is systematic protective painting. Foot over bridges are easily accessible for inspection. These girders are prone to corrosion on account of rough public use and formation of water pockets, particularly, at bases of columns, staircase stringers, etc. These pockets can be filled with concrete or bitumen-mixed sand to avoid water stagnation. There are very remote chances of the rivets becoming loose even after 80 to 90 years of service life. FOBs constructed after 1970 are of welded construction and welded joints are generally holding good without any defects.

5.1.2 Road over-bridges

Old steel girders used for road bridges are mostly with

the same design loading criteria of track bridges and hence lot of reserve strength is available as highway loading standard is lower than railway loading. Besides these rubber tyred wheels of road vehicles cause less impact. These girders are generally provided with bronze bearings. Hence periodical greasing of bearings is not required except periodical cleaning and painting to avoid corrosion on account of muck accumulation but no lifting of girder is involved. Proper protective painting is a major maintenance work. To avoid sagging of girder one should ensure that no dead load is increased on account of additional road metal used during repairs of road surface carried out by road authority. This aspect should be checked during inspection. In past, rivets have been found to be corroded, rather than loose. After 1975 most of the ROBs are constructed with RCC deck with PSC girders. Recently most of the ROB's are being made composite structures. The composite and RCC / PSC girders are provided with maintenance-free elastomeric bearings. Main area of concern is the shear connector between the steel beam and concern slab. These locations are to be looked for cracks. Development of crack separates steel and concrete portion of composite girder thus making structure weak and causing excessive sagging or loss of camber. Hence except inspection and ensuring no loss of camber, no maintenance is required, if the initial quality of construction is good.

5.1.3 Track bridges

Steel girders used for track bridges are dynamically loaded structures. There is a constant, albeit

imperceptible movement taking place in bridge girders and hence bearings are provided to take care of these movements. Therefore all items of maintenance mentioned in Para 5.1 are applicable to steel girder bridge for railway track.

5.2 INSPECTION OF STEEL GIRDER

Inspection is also a part of maintenance work. Steel girders used for foot over-bridges and road over-bridges do not show much structural distress during inspection for reasons mentioned above. Steel girders used for track bridges require critical "crow eye" inspection. It is also essential to maintain systematic recording of inspection notes to build past history. The inspection equipments have been dealt in the Chapter – 4 of this book; Indian Railway Bridge Manual may also be referred for further details.

Some common problems of major parts of steel girder, their possible cause and suggested Remedial measures are discussed below.

Table : 5.0 Common problems of steel girder, causes & suggested remedies

SN	Visible Symptom	Possible Cause	Remedial Measures
A.	**BEARING OF GIRDERS**		
1	**Sliding Bearing**		
	Corroded but not Sezied	Cleaning and Greasing not done	Clean and Grease it
	Corroded and Sezied	Cleaning and Greasing not done	Replace it

Table Contd...

Table : 5.0 continued from previous page

SN	Visible Symptom	Possible Cause	Remedial Measures
	Irregular gaps between Bearing Strip and Location Strips	Movement of girders	Pull back the girders (if end span hits the Ballast Retainers)
	Sheared Location Strips and / or Sheared Anchor Bolts	Excessive Movement of girder / Sliding or Tilting of Substructure	Check the Movement of Girder Strengthen the Approaches Repair the Sheared Parts, Observe the pier for possible damage, if any rectify it.
	Impact at Bearing (Floating)	Incorrect levels of Bed Blocks	Check the levels of Bed Blocks and Provide a Layer of Epoxy Mortar in the Gaps
2	**Roller & Rocker Bearing**		
	Corroded but not Seized	Cleaning and Greasing not done	Clean and Grease it
	Corroded and Sezied	Cleaning and Greasing not done	Replace it
	Flattening of Rollers (Ovality) / Cracking	Excessive load or poor Roller material, Part corrosion	Replace the Rollers
	Impact at Bearing (Floating)	Incorrect Levels of Bed Block	Check the level of Bed blocks and Provide a layer of Epoxy Mortar.

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SN	Visible Symptom	Possible Cause	Remedial Measures
3	**Elastomeric Bearings** Tearing / Cracking / Bulging	Inferior Quality Material, Weathering	Replace the Bearing with Good Quality Bearing
4	**All Bearings** Displacement	Settlement / Scour under Pier	Corrective action at Pier / Foundation is needed after inspection.
B.	**SUPERSTRUCTURE**		
1	**Plate Girders**		
	Early Steel	Material	Replace the Girder Check with reduced Stresses
	Weathered Paint Surface	Weathering	Patch Painting
	Flaking / Peeling of Steel	Corrosion	Complete Painting
	Distortion of Bracings	Accidents / Inadequate Section	Change the Bracings Also check for its Adequacy
	Distortion of Stiffeners	Overload	May be due to Overload impose SR till rectification Redesign and provide a Heavier Section
	Loose Rivets at Floor System Joints	Overloaded / Bad Quality of Rivetting	Replace the Rivets (HSFG Bolts can not be used to replace Isolated Loose Rivets)
	Cracks in Steel works		Same as mentioned in Open Web Girders

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SN	Visible Symptom	Possible Cause	Remedial Measures
2	**Open Web Girders**		
	Early Steel	Material	Replace the Girder Check with reduced Stresses
	Weathered Paint Surface	Weathering	Painting
	Flaking and Peeling of	Corrosion Stee	Provide Cover Plates / Complete Painting
	Distortion of Bracings Section	Accident / Inadequate	Change the Bracings Also check for its Adequacy
	Distortion of Stiffeners	Overload	May be due to Overload (SR) Redesign and provide a Heavier Section
	Loose (Field) Rivets at Floor System	Overload / Bad Joints Riveting	Replace the Rivets HSFG Bolts cannot be used to replace Isolated Loose Rivets
	Loose (Field) Rivets at Main Chord Joints	Overload / Bad Riveting	Lift the Panel Joint
	Progressive Loss of Camber (needs to be reliably established)	Overload / Bad Riveting	May be due to Overload or Bad Riveting. Check for Stresses and Strengthen it.
	Rust mark over Metalized surface	Possibility of Crack / Loose rivet at Joint	Regirder the Bridge a) Whenever crack is detected in steel work, its cause should be established and further propagation, if any, monitored. If the crack is propagating in

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SN	Visible Symptom	Possible Cause	Remedial Measures
			a direction perpendicular to the stress in member, holes 20 or 22 mm dia may be drilled at crack ends to arrest the crack propagation. The edge of holes should be placed at visible ends of the crack. After holes are drilled it should be checked that crack tips have been removed and turned bolts of 20 or 22 mm dia as the case may be should be provided in the holes and fully tightened. Any reduction in strength of girder due to the crack and drill of holes should be given due to consideration. b) The method of repair of crack should be decided based on the location and severity of the crack. As a long term solution the cracked member may be strengthened by cover plate (s), adequately rivetted. If this is not feasible, the defective member may have to be taken out and

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SN	Visible Symptom	Possible Cause	Remedial Measures
			repaired / replaced. c) Permanent measures may consist of the cracked member being retrofitted with rivetted or bolted splice or where feasible the entire member may be replaced. d) Field welding should not be undertaken for repair of cracks.
3	**Composite Girders**		
	Separation of the Concrete or Crack in Concrete Slab	Loss of Bond in Shear or poor casting of Concrete.	If separation of the concrete deck slab from the steel girder is noticed, the location and length should be marked distinctly with Paint for easy identification. Repair and retrofit scheme should be prepared after fully investigating the cause of the problem. Epoxy grouting may be done to bind the deck slab and the girder where the defect is noticed and the girder should be kept under close observation. If the epoxy grouting is not found effective, vertical prestressing or strapping may be necessary for which

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SN	Visible Symptom	Possible Cause	Remedial Measures
			holes should be drilled in the deck slab near the girder in the affected location and vertical prestressing / strapping provided.
	Defects in steel portion		- Similar action as mentioned under heading of the steel girders.
	Loose / broken HSFG Bolts	Poor Workman ship	- These bolts shall be replaced expeditiously by new HSFG bolts of same specifications & properly tightened. Retightening of loose HSFG bolts is not allowed in any case. - The bolt threads may be destroyed to prevent theft / sabotage.

5.3 MAINTENANCE OF BEARINGS

5.3.1 General maintenance of bearings

The surrounding area of the bearings shall always be kept clean and dry to avoid damage to the bearings. Suitable easy access to the bearing shall be provided for inspection and maintenance. Provision shall be made for jacking up the superstructure so as to allow repair/replacement of the bearings. Inspection of bearing at site is required from time to time to ascertain the performance of the bearings. Periodic nominal maintenance of bearing shall be carried out In order to ensure better performance and longer life. The results of every inspection shall be recorded in the inspection

report and shall be rectified within reasonable time.

All the steel girders of track bridges are presently provided with metal bearings. Steel bearing plates or steel rollers normally move on steel base plates. To avoid ill effects of corrosion and ensure easy movement of steel girders periodical greasing of steel bearing is essential.

a) Maintenance of sliding bearings

All standard deck type plate girders are provided with centralized articulated bearings. Both ends of girders are free to move in longitudinal direction therefore greasing between sliding parts of both ends is must. The bearings of all girder bridges should be generally cleaned and greased once in three years. In case of bridge carries LWR, lubrication of bearing shall be done ones in two years. As per item no. 1046 of BSC-82; the Railway Board has ordered that RDSO shall issue necessary C/S indicating necessary conditions to carry LWR over Girder Bridge. In the case of flat bearings, the girder is lifted a little over 6 mm and bearing surfaces is cleaned with kerosene oil. Then a mixture of black oil, grease and graphite in a working proportion shall be applied between surfaces of the flat bearings and then the girder is lowered. For spans above 12.2 m, special jacking beams shall be inserted to apply jacks and to lift the girders.

Modus operandi of cleaning and greasing of steel sliding bearing

Lifting of girders - For greasing of the bearings, the girders are required to be lifted. But the gap between

the bottom flange of plate girders and the bed block generally varies from 100 mm to 150 mm. The normally available standard jacks have a closed height of 300 mm. These jacks, therefore, can't be used for lifting the girders unless special jacking arrangements are made. The safest arrangement for Jacking is shown in Fig 5.1. However for different span this arrangement could be as follows:

1. For plate girders upto 6.1 m span, jacks can be directly applied below end sleeper after ensuring firm hook bolt connection, since load to be lifted is about 4 to 5 ton.
2. Jacking arrangement for span 9.15 m plate girder requires provision of a hard wood beam below inner top flange for lifting the girder.
3. Jacking arrangement for span 12.2, 18.3, 24.4 and 30.5 m plate girder requires provision of a steel beam to be placed below the inner top flange for lifting the girder.

The provision of jacking steel beam and its removal is difficult. It requires more man power and also it is time-consuming on account of heavy weight of the beam and limited working space on bridge piers. Field officials, many times, apply jack to the end cross frame angle (diagonal) to avoid provision of the jacking beam, to lift the girder. This may cause bending of the angle on account of its slender size, which results in lifting of bearing strips inside when lowered on base plate. This improper seating of the bearing strip will cause hammering action during subsequent passage of train resulting in damage to the bed block and masonry of

the substructure. Therefore the method of provision of jacking beam to outside girder as shown in Fig 5.1 is preferable. This requires less manpower and less time for lifting of the girder.

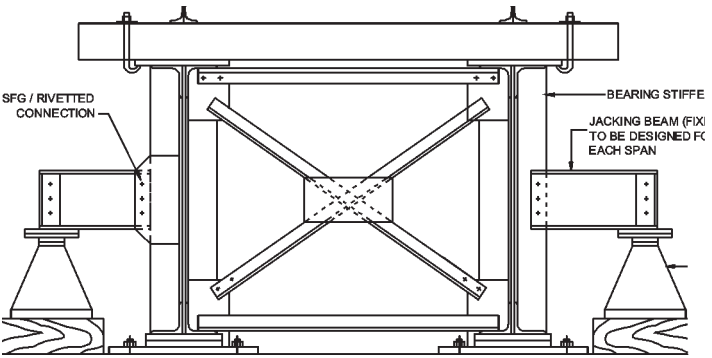


Fig-5.1 Jacking arrangement for 12.2m, 18.3m & 24.4m spans

Cleaning and greasing of steel sliding bearings - Following equipments are required for greasing of steel sliding bearings:

1. Jacks (50 ton capacity) - 2 nos.
2. Hard wooden packing below and above jack
3. Grease graphite Grade 3 conforming to 1S:508
4. Kerosene or released black oil for cleaning
5. 6 mm thick steel scrapers
6. Mortar pan
7. Cotton waste

Greasing of sliding bearings can be undertaken without "Block" under traffic with issue of caution order and line protection for temporary works as per provision of

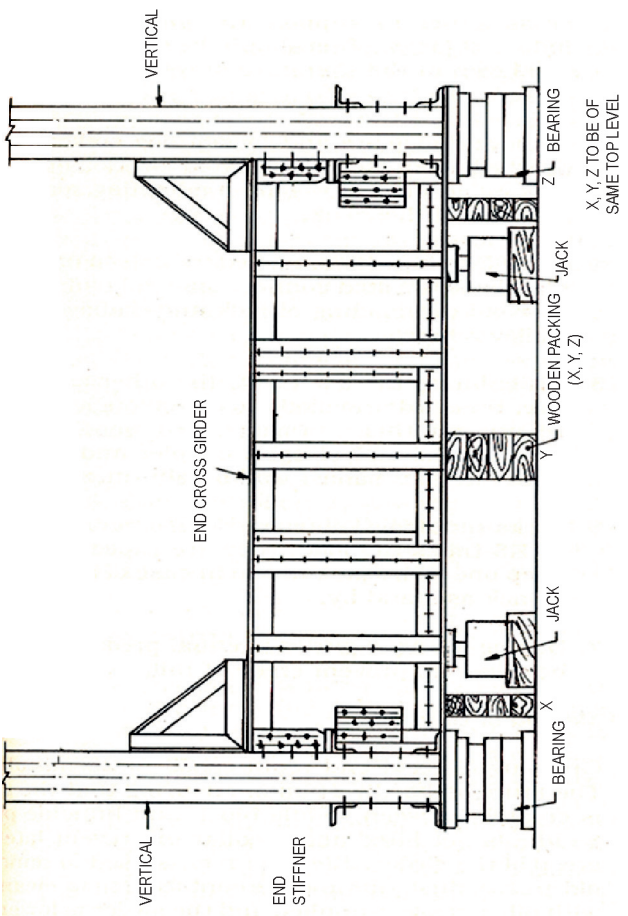


Fig.5.2 Typical arrangement for cleaning and greasing of Open web girder

IRPWM.
Lifting of girder should be restricted to 8 to 10 mm only, ensuring that the bearing strip does not get lifted over locking strip and guide strip to avoid creep of girder in logitudinal and lateral direction. For lifting, it is not necessary to cut the rails or remove the fish plates, loosening of fish bolts and dog spikes over a small length on both sides of the pier is sufficient. One end of the girder should be lifted at a time and steel scraper inserted between bearing strip and base plate to remove old grease dust and dirt. The contact surface is now cleaned with kerosene oil and then grease is applied. Girder is then lowered back on the base plate.

Time required for all these activities is approximately 15 to 20 minutes.

b) Maintenance of Roller & Rocker steel bearing

All open web through spans are provided with rockers and rocker cum roller bearings. These bearings need greasing between roller and base plate of free end and between curved knuckle slab and saddle block of both ends.

Modus operandi of Cleaning and greasing of Rocker & Roller bearings of open web through girders

The rollers and rockers are lifted from their position by adequate slinging. The bearings are scraped, polished with zero grade sand paper and grease graphite of sufficient quantity to keep surfaces smooth should be applied evenly over the bearings, rockers and rollers before the bearings are lowered. The knuckle pins of both the free and fixed end should also be greased at this time. While lifting fixed ends, the space between girders (in case of piers), or between the girder and the ballast wall (in case of abutment), at free ends should be jammed with wedges to prevent

longitudinal movement of the girder.

In case of standard open web through girders, no separate jacking arrangement is required as the end cross girders are designed and provided with stiffener and pad plate for provision of jack for lifting. Gap between bottom of cross girder and top of bed block is about 600 mm; hence any type of jack of 100 t to 200 t capacity can easily be used for lifting. In case of non standard spans, the end cross girder requires adequate strengthening or special jacking beam below the bottom boom. In addition to this the equipment required are wire rope with turn buckle arrangement for holding the free end and all other equipments used for oiling and greasing of steel sliding bearing. A typical arrangement for cleaning and greasing of OWG is shown in Fig.5.2

Greasing of rocker and roller bearing should be carried out in traffic block under the supervision of an official not below the rank of ADEN/ABE.

Lifting of girder - Following precautions and preliminary lifting of girder arrangements are required:

i. Ensure tightness of rivets connecting end cross girder and end panel point of truss.

ii. Provide hard wooden packing below the end cross girder to support the girder in case of failure of jacks. This should be done at three places to prevent tilting of this girder.

iii. Remove fish plates and rail sleeper fastenings over adjacent spans to avoid overloading the jack on account of weight of adjoining span and stiffness of the track.

iv. If trolley refuge is connected to both spans on any pier, loosen the bolted connection of

adjoining span to avoid overloading of jack and damage to the trolley refuge.

v. While lifting the fixed end, the other end being free, the girder is likely to creep longitudinally. To prevent this, provide hard wood packing between the ends of girder on pier and between girder and the ballast wall on abutment.

vi. Jacks should be kept in working order and tested to 1.5 times the load they are expected to lift. Keep one spare jack as stand by.

vii. During lifting of girder, precaution should be taken to prevent creep of rail.

Method of Greasing - Greasing of fixed end requires 20 to 25 minutes. The lifting is hardly 10 mm, ensuring that the gap is created between saddle block and knuckle pin. Saddle is not lifted above collar to prevent lateral creep of the girder. Steel scraper is used to remove old grease, dust and dirt. The contact area is cleaned with oil. Grease is applied and then girder is lowered back.

Greasing of free end requires 45 to 50 minutes. Knuckle plate is tied to the saddle plate with wire rope having turn buckle arrangement to release the load from roller when the girder is lifted.

When the girder is lifted about 10 mm and rollers are free, link plate and tooth bar are removed after opening the stud connections. All rollers should be taken out and cleaned with scraper and oil, polished using fine sandpaper of zero grade. Rollers should be examined

for any possible signs of flattening or minute cracks with a magnifying glass. Grease graphite grade 3 conforming to IS 508 is applied over the base plate evenly below the roller contact area. The rollers are then placed in position and grease applied at the top contact surface. Link plate and tooth bars are connected with care so that tooth bar is placed in the same inclination as per the drawing.

With the help of turn buckle of wire rope sling, the knuckle plate is lowered over the rollers. This will create gap between the saddle block and knuckle plate. Cleaning and greasing of this area is then carried out similar to the fixed end and then the girder is lowered back. While taking out rollers for examination and greasing, take special precautions to prevent the rollers from falling-off the bed block.

c) Maintenance of other types of bearings –

Phosphor bronze sliding bearing – Composite girders and open web underslung girders are provided with bronze bearings or elastomeric bearings. Steel bearing plate or knuckle plate will slide on bronze plates which has low friction. Phosphor bronze bearings need not be greased as they are corrosion resistant and retain the smooth surface and consequently the initial coefficient of friction is limited to 0.15. Periodical cleaning of base plates around bearings is essential to avoid damage of smooth bronze surface by the accumulation of dust and sand particles. No lifting, of girders is involved.

Oil Bath bearings – Oil bath bearing are essentially Roller cum Rocker bearing kept submerged in a pool of oil. Girders above 76.2 meter spans are provided with

oil bath bearings and hence no greasing is required. The oil in oil bath bearing shall be topped up every year and shall be replaced once in every five years.

d) Maintenance of elastomeric bearings

Generally, malfunctioning of the elastomeric pad would result in distress either in the girder or in bed block and the area close to the bearing should be examined for cracking or spalling of concrete. Elastomeric bearings may require replacement every fifteen or twenty years. Therefore elastomeric bearing should not be fixed in position by applying adhesive. For this purpose, the girder (steel, R.C.C. or P.S.C.) will have to be lifted up at predesigned and predetermined locations.

e) Maintenance of Pot-cum-PTFE bearings

New girders with very long spans are provided with POT Cum PTFE bearings. The Pot-cum-PTFE bearings are designed and manufactured so as to make it almost maintenance free. However, in case of damages to the bearing or the defects which causes the bearing to cease its function may be referred to the manufacturer for rectification/ replacement.

Note: For detailed information on inspection and maintenance please refer IRICEN publication on bearing.

5.4 PROTECTIVE PAINTING OF STEEL GIRDERS

On Indian Railways a major part of expenditure on maintenance of steel girders is spent on painting of steel girders. Experience gained during the past 100 years is

that proper protective painting along with greasing of bearings are the only factors for economical service life of steel girders. It is noted that the steel rolled prior to 1975 has more corrosion resistance than the steel rolled after 1975. The new girders provided during doubling of lines have more corrosion problems than old girders. Corrosion is more where steel comes in contact with wood and water stagnation in pockets formed on account of structural detailing.

Steel girder bridges situated in the following locations are prone to severe corrosion:

1) Where humidity in atmosphere is more than 80%
2) Coastal areas
3) Bridges across creeks
4) Bridges surrounded by chemical industry
5) Bridges near metropolitan city on account of public nuisance.

In addition to above, type of traffic carried on bridges i.e. salt, fish, manure and chemicals also cause severe corrosion.

Maintenance engineer has to adopt proper painting scheme during maintenance as stipulated in IRS-B1-2001 depending upon the location of bridges.

During service life of steel girders, it is observed that at first the deterioration takes place of the finish coat of paint. Hence, if finish coat is only painted over intact base coat it will derive maximum saving in expenditure than full painting.

Plate girders of track bridges have less water stagnation pocket and 80% steel surface is in vertical position hence these girders are not prone to corrosion except top flange plates (below sleeper). Also provision of staging's for quality painting work is easy under traffic on account of steel surface being below the rail level. Painting with suitable scheme described in this chapter can be adopted for locations depending on the severity of corrosion.

In open web through type steel girders of track bridges, it is very difficult and costly to provide proper staging for surface preparation and application of paint under traffic for quality paint work. Open web truss span has more water stagnation pockets than plate girder on account of form of members and joints. Any structural repairs or strengthening of open web steel girder is very difficult and costly under traffic. Owing to these problems it is recommended to provide the long life painting scheme for steel girders of through type open web track bridge in all locations to derive prolonged paint life for economical maintenance. Surface preparation of the steel to receive the paint should be as prescribed in item 217 para 1 of Indian Railway Bridge Manual 1998.

5.4.1 Painting of girder bridges

Girder painting is essentially an application of surface coating to the steel work so as to inhibit corrosion. The basic principle underlying maintenance painting is not to allow deterioration of existing paint film to reach such a stage that rusting starts underneath the paint film.

5.4.2 Surface preparation

Correct surface preparation is the most important single

factor in ensuring good performance of a painting scheme applied to steel work. The duration of protection afforded by a given painting scheme when applied to a well-prepared surface is many times more as compared to that obtained on a badly prepared surface. Removal of rust, oil, grease and dirt is necessary to ensure adequate adhesion of paint film to the surface. During maintenance, the surface preparation before painting depends upon the condition of the existing paint film.

1. When only the finishing coat of paint shows signs of deterioration, the surface should be washed with lukewarm water containing 1 to 2% detergent to remove salt deposits and grime. After this, the surface is to be dried, lightly wire brushed and sand papered. On this prepared surface, finishing coat of paint is to be applied.

2. When the parent metal is exposed and portions of girders show signs of corrosion, the surface preparation is done in the following manner:

   i) **Sand or grit blasting :-** This is one of the best method of surface preparation by which the surface can be completely cleared of mill scale and rust. A properly sand blasted steel surface appears silvery grey in colour.

   ii) **Scraping, chipping and wire brushing :-** In this method, the surface is scraped, chipped and wire brushed manually or by power tools so as to remove the mill scale and rust. Finally, the surface is sand-papered and dusted. The surface prepared by this method

is of a lower standard than the one prepared by the sand blasting.

iii) **Flame cleaning :-** By directing an oxyacetylene flame on the steel surface and then wire brushing is another method. Though it is inferior to grit blasting, it is a good method for use with excessively rusted surface. Flame cleaning should not be done on plates with thicknesses 10 mm or less as it may lead to permanent distortion of such plates. The surface being flame cleaned should not be exposed to the flame for a longer time. After passage of flame the surface is cleaned by wire brush, sand papered and dusted.

iv) **Temporary coatings** :- If for any reason, painting cannot immediately follow surface preparation, corrosion can be prevented for a short time by means of temporary coating of linseed oil applied uniformly and thinly (one third litre on 10 m^2 area will be sufficient). Modern pre-fabrication primers are available, which may be used instead of linseed oil.

5.4.3 Painting scheme with ordinary paint

Surface preparation – Any one of the above methods described for surface preparation may be used depending upon the extent of painting work.

The following painting schedule is to be adopted in areas where corrosion is NOT SEVERE.

1. Priming coat

One coat of ready mixed paint zinc chromate priming to IS:104, followed by one coat of ready mixed paint red oxide zinc chrome priming to IS:2074.

OR

Two coats of zinc chromate red oxide primer to IRS–P 31

2. Finishing coat

Two cover coats of Paint to IS:13607 with colour specified by Zonal Railway or any other approved paint applied over the primer coats.

The painting scheme for girders in areas where corrosion is SEVERE is given below.

1. Priming coat

One coat of ready mixed paint zinc chromate priming to IS:104, followed by one coat of ready mixed paint red oxide zinc chrome priming to IS:2074.

OR

One Coat of ready mixed paint zinc chromate priming to IS : 104 followed by one coat of zinc chrome - red oxide priming to IS : 2074

ii) Finishing coat :

Two coats of aluminium paint to IS : 2339

c) In case where the priming coat is in good condition the steel work is painted with two coats of paint to IS : 13607 with colour/shade

to be specified by Zonal Railway or paint aluminium to IS : 2339 depending on the severity of corrosion.

Note : (i)The colour/shade of finishing coat should be generally matching with the Smoke Grey colour/shade No. ISC 692 mentioned in IS : 5-2004.

(ii) The colour/shade can be changed by CBE as per the local requirments.

2. Finishing coat

Two coats of aluminium paint to IS: 2339

5.4.4 Long life painting scheme

For locations where girders are exposed to corrosive environment i.e. flooring system of open web girders in all cases, girders in industrial, suburban or coastal areas etc., protective coating by way of metallising or by painting with epoxy based paints may be applied.

Surface preparation using sand / iron grit blasting

a) The surface of steel shall be free from oil, grease, bituminous materials or other foreign matter, and shall provide an adequate key for the sprayed metallic coating. This may be achieved by flame cleaning or by sand blasting. However, the abrasive once used for cleaning heavily contaminated surface should not be reused even though rescreened.

b) Final cleaning is done by abrasives i.e. Chilled iron grit G.24, as defined in BS : 2451

or Washed salt free angular silica sand of mesh size 12 to 30 with a minimum of 40% retained on a 20 mesh screen, as per following details :

Air Pressure: Not less than 2.109 kg per sq.cm.

Nozzle position: At right angles to and approximately 22.5 cm. from the surface

Nozzle dia : Not exceeding 12 mm

c) The final surface roughness achieved shall be comparable to roughness with a reference surface produced in accordance with Appendix A of IS : 5909 and shall provide an adequate key for subsequently sprayed metal.

5.4.5 Metallising

In metallised protection base metal like zinc or aluminium is lost by the atmospheric action, while the base metal (steel) remains unaffected. Aluminium can be sprayed on the surface prepared by grit/sand blasting for giving such protection, known as metallising.

i) Surface preparation-

a) Remove oil/grease from the metal surface by using petroleum hydrocarbon solvent to IS : 1745.

b) Prepare the surface by sand or grit blasting to Sa 2½ to IS : 9954 i.e. near white metallic surface.

ii) Metallising process :

a) The sprayed coating shall be applied as soon as possible after surface preparation. The wire method shall be used for this purpose, the diameter of the wire being 3 mm or 5 mm. The composition of the aluminium to be sprayed shall be preferably in accordance with BS : 1475, material 1-B (99.5%) aluminium otherwise as per IS : 739. Fig 5.3 shows metallising process.

b) Clean dry air at a pressure of not less than 4.218 kg per sq.cm. shall be used. The minimum thickness of metal coating applied shall be 110 μ and average thickness 150 μ.

c) The specified thickness of coating shall be applied in multiple layers, not less than two. The surface after spraying shall be free from uncoated parts or lumps of loosely spattered metal.

d) Atleast one layer of the coating must be applied within 4 hours of blasting and the surface must be finished to the specified thickness within 8 hours of blasting.



Fig 5.3 (a) Metallising of steel girder



Fig 5.3 (b) Metallising gun

iii) Inspection :

a) The metal coating shall be checked for thickness by an approved magnetic thickness measuring gauge. Minimum metal coat shall be 110 μ but average thickness shall be 150 μ. The frequency of testing shall be atleast one test per m^2 of painted area.

b) The calibration of the gauge should be checked against a standard of similar thickness within an accuracy of 10 percent.

c) Adhesion Test: To check if the metallising layer has good adhesion with the steel surface, i.e. to verify if the cleaning / blasting has been done properly and the blasted surface has sufficient roughness to ensure the metallising layer to have good adhesion, an adhesion test shall be performed. For this, hardened steel scribe ground to a sharp 30° point shall be taken. Using this scribe, make two parallel lines at a distance apart equal to approximately 10 times the average

coating thickness. In scribing the two lines, apply enough pressure on each occasion to cut through the coating to the base metal in a single stroke. If a surface is properly metallised, the metallising layer between the two lines shall not come off.

iv) Finishing coat of painting :

a) After the metallising, any oil, grease etc. should be removed by thorough wash with a suitable thinner and allowed to dry for 15 minutes. The painting may be applied by brush or by spray. The first coat shall be wash primer to SSPCPT - 3 53T or Etch primer to IS : 5666.

b) The second coat shall be zinc chromate primer to IS : 104. The zinc chrome should confirm to type 2 of IS : 51. The 3rd and 4th coats shall be aluminium paint to IS : 2339.

v) Maintenance painting of metallised girders :

a) The need for periodical repainting and the method to be lowed will depend on the condition of the existing paint. In most cases complete removal of existing paint film may not be necessary.

b) The surface is cleaned of all oil, dirt and other foreign material. If the existing top coats of aluminium paint are found to be in good condition, it will be sufficient to apply one additional coat of the same paint, once in 5 years or at such closer intervals as specified.

c) However, if the existing paint is found flaked or damaged, it should be removed completely by wire brushing without the use of scrapers or chipping tools. In case the original coat of zinc chromate primer is also damaged in patches, such patches should be painted with fresh zinc chromate primer before applying the finishing coat of aluminium.

d) In the event of any localised damage to the metallised coating of aluminium, as evidenced by traces of rust, the affected portion should be thoroughly cleaned of all rust before the priming and top coats of paints are applied. Rust streaks caused by droppings from the track or by contact with hook bolt lips should not be mistaken for corrosion.

vi) Precautions to be taken while inspecting metallised girders :

The use of testing hammers for rivet testing, or any other operation shall not be resorted to since these can damage the metallised coating. Any looseness of the rivets in bracings etc. may be detected from visible signs such as the appearance of rust under the rivet head.

5.4.6 Epoxy painting

Epoxy paints have good adhesion and abrasion power. Epoxy based paints can be used in lieu of metallising in the field for existing girders.

5.4.6.1 Scheme of epoxy based paint

i) Surface preparation-

a) Remove oil/grease from the metal surface by using petroleum hydrocarbon solvent to IS : 1745.

b) Prepare the surface by sand or grit blasting to Sa 2½ to IS : 9954 i.e. near white metallic surface.

ii) Painting :

a) **Primer coat -** Apply by brush / airless spray two coats of epoxy zinc phosphate primer to RDSO specification No. M & C /PCN-102/ 86 to 60 microns minimum dry film thickness (DFT) giving sufficient time gap between two coats to enable first coat of primer to hard dry.

b) **Intermediate coat -** Apply by brush/airless spray-one coat of epoxy micaceous iron oxide to RDSO specification No. M & C / PCN-103/86 to 100 microns minimum DFT and allow it to hard dry.

c) **Finishing coat -** Apply by brush/airless spray two coats of polyurethane aluminium finishing to RDSO Specification No. M & C /PCN- 110/88 for coastal locations or polyurethane red oxide (red oxide to ISC 446 as per IS : 5) to RDSO Specification No. M&C/PCN-109/88 for other locations to 40 microns minimum DFT giving sufficient time gap between two coats to enable the first

coat to hard dry. The finishing coats to be applied in shop and touched after erection, if necessary.

Use of epoxy painting system for railway girders has been introduced recently. Real benefit of epoxy painting can be achieved with longer life of paint than frequent oil painting which is more costly for maintenance of steel girders on existing bridges. Life of epoxy painting is 12 to 15 years if correct epoxy scheme is selected.

5.4.7 Important precautions during painting -

a) Paints from approved manufacturers only should be used.

b) Dust settled after scraping shall be cleaned before applying paint.

c) Special care should be taken to shift sleepers on girders or rail bearers to clean the seating very thoroughly before applying the paint.

d) Paint should be mixed in small quantities sufficient to be consumed within 1 hour in the case of red lead paint and 5 days in the case of red oxide paint.

e) While painting (Ref IS : 13607) with red oxide paint, a little quantity of lamp black shall be added to the paint while doing the first coat to distinguish it from the second coat. Similarly, in case of aluminium paint a little blue paint can be added instead of lamp black for 1st coat.

f) Paints should be used within the prescribed

shelf life from the date of manufacture. The quantity of paint procured should be such that it is fully utilized before the period prescribed for its use.

The shelf life of various paints used in the Railways are as follows:

i) Paint Ready Mix Zinc crome primer (IS : 104) : 1 Year

ii) Paint to IS : 13607 with colour specified by Zonal Railway : 1 Year

iii) Paint Aluminum :

When paste and oil are not mixed :1Year

When paste and oil are mixed : 4 Month

iv) Oil linseed boiled : 2 years

v) Paint Ready Mix Red Oxide Zinc Crome (IS : 2074) : 1 Year

vi) Red Oxide Zinc Cromate Primer (IRS-P-31) : 1 Year

g) Brush shall not be less than 5 cm in width and should have good flexible bristles. A new brush, before use, should be soaked in raw linseed oil for at least 24 hours. The brushes shall be cleaned in linseed oil at the end of each day's work.

h) When the paint is applied by brush, the brush shall be held at 45^0 to the surface and paint applied with several light vertical/lateral strokes turning the brush frequently and transferring the paint and covering the whole surface. After this, the brush shall be used

cross wise for complete coverage and finally finished with vertical/lateral strokes to achieve uniform and even surface.

j) Rags, waste cotton, cloth or similar articles should not be used for applying paint.

k) The coat of paint applied shall be such that the prescribed dry film thickness is achieved by actual trial for the particular brand of paint. The applied coat of paint shall be uniform and free from brush marks, sags, blemishes, scattering, crawling, uneven thickness, holes, lap marks, lifting, peeling, staining, cracking, checking, scaling, holidays and allegatoring.

l) Each coat of paint shall be left to dry till it sufficiently hardens before the subsequent coat is applied.

m) The entire content of a paint drum should be mixed thoroughly either by pouring a number of times or by mechanical mixing to get uniform consistency. The paint should not be allowed to settle down during painting by frequent stirring or mixing. Driers such as spirit or turpentine should not be used. Mixing of kerosene oil is strictly prohibited.

n) The maximum time lag between successive operations as indicated below shall not be exceeded.

i) Between surface preparation and the application of primer coat	24 hrs
ii) Between surface preparation and 1st finishing coat in the case	48 hrs

of patch painting

iii) Between the primer coat and the 1st finishing coat — 7 days

iv) Between the 1st finishing coat and the 2nd finishing coat — 7 days

5.5 REPLACEMENT OF LOOSE RIVETS

5.5.1 General

Site driven rivets are generally used for connecting splice joints and joining secondary members with primary members. These rivets directly transfer load or subject to heavy vibration, contrary to shop rivets which generally are stitch rivets. Therefore, rivets which are driven at site and rivets which are subjected to heavy vibrations are prone to get loose. Corrosion around rivets also causes their loosening.

Some of critical areas for loose rivets could be Top flange of plate girders, Splice joints, Connection between rail bearer and cross girders in open web girders, Connection between cross girders and bottom/ top boom in open web girders and Gussets at panel points of open web girders.

Slight slackness of rivet does not cause loss of rivet strength to great extent.

ii) Renewal of slack rivets should be done only when the slack rivets are in groups or are

bunched up. Individual scattered slack rivets need not be touched.

iii) Rivet is to be considered finger loose when the looseness can be felt by mere touch, without tapping. Rivets should be considered hammer loose, when the looseness can be felt only with the aid of a hand hammer.

Loose rivets occur more frequently at certain locations especially where dynamic stresses, reversal of stresses and vibrations are at their maximum. Similarly in-situ rivet connections are carried out under less ideal conditions than in the case of shop rivets and hence the incidence of loose rivets is likely to be more at such joints.

5.5.2 Following tools and plants are required for replacement of loose rivets at site

a) Air compressor
b) Pipeline with connections (for long bridges, air receiver is required to maintain the air pressure)
c) Hand pneumatic rivet hammer
d) Pneumatic dolly or Holder on
e) Hand dolly
f) Rivet heating forge
g) Rivet tong
h) Charcoal
i) Proper staging as working platform.

5.5.3 Replacement of loose rivets

For replacing loose rivets, existing rivet head is to be

cut and rivet is to be punched out. For this either hand chisel and hand hammer or pneumatic operated rivet cutting machine called "Buster machine" is used. Rivet buster cuts the head in shear imparting a very heavy shock to adjoining rivets in group, resulting in loosening of sound adjoining rivets. Therefore, when a few rivets at staggered locations in any joint of open web girder are required to be replaced, it is a common practice to drill the rivet out and cut so that it will avoid loosening of adjoining rivets. If 70 to 80% of rivets in one joint or entire joint rivets require replacement, rivets will be cut by buster for speedy work. One should ensure that in any joint of open web girder not more than 10% rivets are cut at one time. When rivet head is cut it should be punched out immediately and turned bolt should be provided in each hole of cut rivet. Under no circumstances blank hole in joint is permitted when train is running on bridge. To ensure these precautions when more number of rivets in joints are to be replaced caution order is issued, protection is provided to stop train if required. It should be ensured that all joint holes should be provided with rivets or turned bolts while train is passing on the bridge. For replacement of rivets other than joints including bracings connections, it is not necessary to issue caution order. At locations where replacing of rivets is not possible, loose rivet should be replaced with proper size turned bolt and threads burred. The guidelines mentioned in the item 215 para 3 of Indian Railway Bridge Manual for replacement of loose rivets in plate girder should be followed.

Following points should be kept in mind while driving rivet for replacement at site:

1) Proper staging for riveter and dollyman is

provided to work free with both hands.

2) 6.5 to 7.6 kg/cm^2 air pressure at riveting machine should be ensured.

3) Rivet shank should be heated uniformly from tip to top to cherry red colour for quality riveting work.

4) Dolly or holder on should be placed properly to hold the other head in proper tight position or otherwise it is the tendency of the rivet to work back while driving the other end for forming head.

5) While driving rivets, riveter should ensure first to squeeze rivet for filling of the cavity in hole and then form the head, by delivering quick hard blows for tightness of rivets.

6) The length of rivet shank may be worked out by the formula -

   L = G + 1.5 D + 1 mm for every 4 mm of grip

   where 'L' is Length of rivet shank in mm, G is Length of grip (joint thickness) in mm and 'D' is Diameter of rivet in mm

7) Rivet should be driven within 20-30 seconds of the rivet leaving the heating forge fire and not after it has been allowed to remain in open space.

8) Rivet hammer must be held straight while driving rivet to ensure coaxial rivet head.

9) Rivets steel should conform to IS : 1148 - 1982.

10) In a joint when only a few rivets are replaced it is very essential that all remaining rivets are checked for tightness by SE/JE Bridges. If any are found loose they should also be

replaced.

11) After completion of replacement of rivets when rivet head is cooled, a base coat paint is provided on the same day and cover coat later on.
12) Rivets should not be replaced in rainy or foggy weather or during early morning hours.

Entry to be made in bridge register as well as in rivet proforma to maintain record for future reference.

5.6 REPLACEMENT OF CORRODED RIVETS

This work is necessitated on account of bad maintenance. Therefore, it is not a structural defect. Rivets are designed for shear stress and 25 to 30% loss of head section will not reduce the strength of rivets. But if the locations of rivets are such that it also cater for tensile stress on account of deflection of member, loss of head of rivet should not be permitted. Apart from this, once corrosion is set in the form of pits, it will continue to corrode even after careful painting. Hence corroded rivets will be required to be replaced. This is a very costly work and maintenance engineer should ensure that this work is reduced to minimum. Procedure for replacement is the same as that of replacement of loose rivets mentioned in Para 5.5.

5.7 REPAIRS TO WELDED JOINTS

Since 1975 all foot over bridges (FOB) are welded constructions irrespective of type of girder i.e plate girder or truss type girders. These girders being statically loaded structure, no weld cracks are reported

so far, except corrosion to weld. Hence no repairs are required for F.O.B. girder frequently.

The use of welded girder for track bridges were started from 1980 on Indian Railways. Components of open web girders are welded but joints are still riveted connections. Track bridge plate girders, either open deck or composite, are fabricated as welded girders. These girders are of beam type (I-Section). Weld joint in plate girders are as follows-

a) Butt joint

b) Fillet Weld joint

The strength of all butt joints is equal to parent metal of steel at those locations and hence radiography test is conducted during fabrication. Therefore, there are remote chances that defect may develop in these welded joints at an early stage.

Crack may exist in fillet weld at the critical location mentioned in para 4.4.4. Initiation and propogation of cracks in welded girder is on account of fatigue or stress concentration or inherent defects which exist during fabrication. Any defects which exist during fabrication will reveal it self within one year of its service life and hence it is essential to check all the welded joints in girder by dye penetration test (DPT) after one year of service.

Fatigue cracks develop in steel girders during service due to repeated loading and its magnitude depends on the magnitude of stress variation, frequency of stress application, type of connection and wedging action due

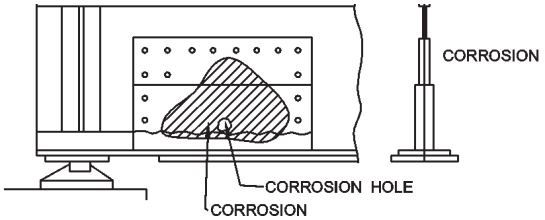
to bending of structure.

Welds are more sensitive to repeated stresses and once cracks occur, they can grow fast and hence weld crack growth is to be prevented.

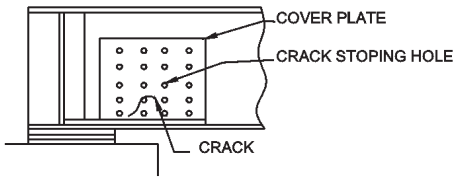
Repairs or retrofit scheme should be decided by design engineer or Chief Bridge Engineer for permanent repairs and hence maintenance engineer should submit report of such defects with sketch or photograph to the Chief Bridge Engineer immediately with provision of temporary measures stated in para 4.5.1 to arrest the crack propagation of welded girder of track bridge. The method of repairs of crack should be decided based on the location and severity of the crack. Permanent measure may consist of the cracked member being retrofitted with rivetted or bolted splice or where feasible the entire member may be replaced.

Site welding is generally prohibited. However, in certain unavoidable cases such as repairs maintenance work for girders in service it can be permitted by Chief Bridge Engineer / officer equivalent to the rank of SAG officer and above. The repair should be done by trained welder under expert supervision of reputed agency and the repaired portions examined by non destructive testing. During construction, it can be permitted on case to case basis by an officer equivalent to the rank of Chief Administrative Officer / Construction and is confined to connections having low stresses, secondary members, bracings etc. The suitability of parent metal to take welding, should, however, be tested first.

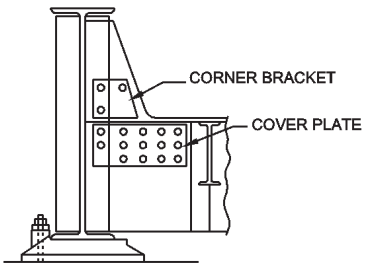
If the crack is in butt weld or 'T' fillet weld connecting flange and web, girder should be taken out by



REPAIRS OF WEB PLATE



CRACK REPAIRS METHOD



STRENGTHENING OF CROSS GIRDER

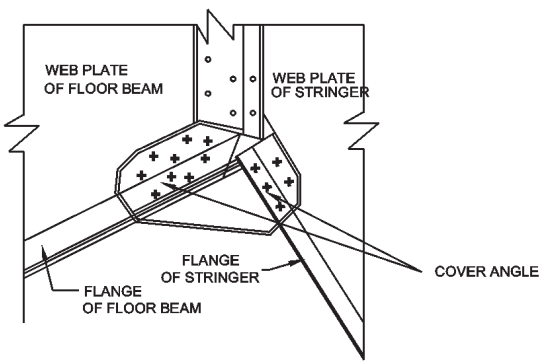


Fig. 5.4 (a) Typical strengthening methods.

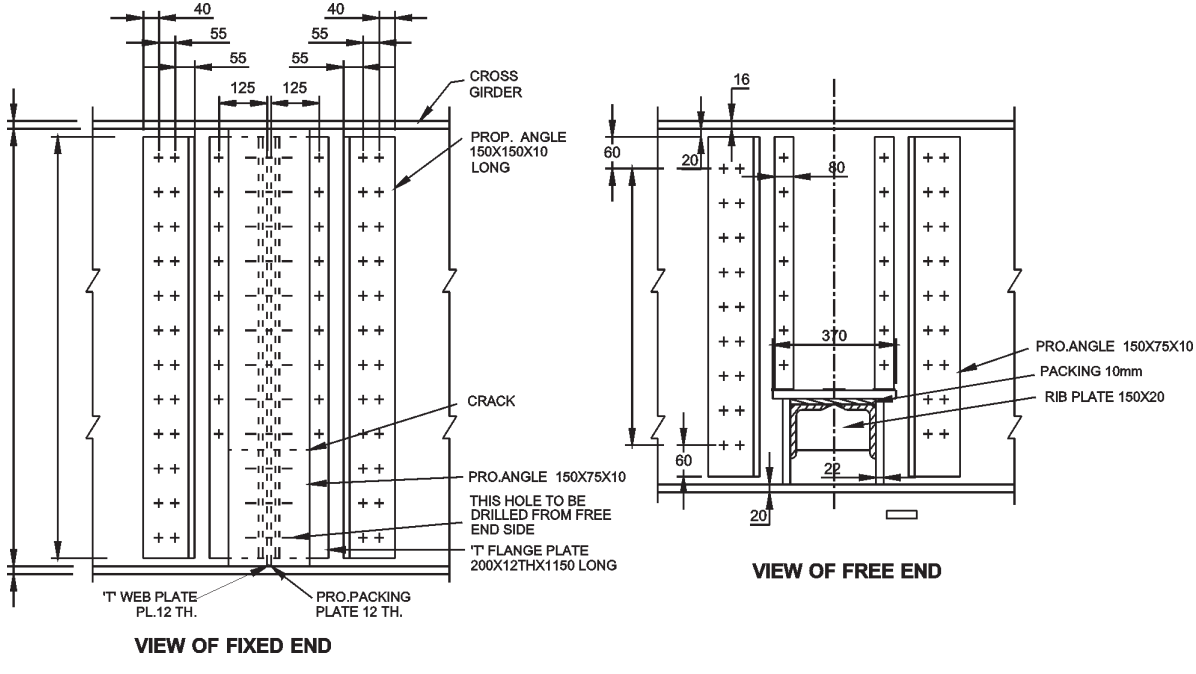


Fig. 5.4 (b) Strengthening of web of cross girder over the cracks.

introducing temporary girder for repairs of weld in down hand position. Such defects are very less in early stage of girder.

Repairs of weld joints of foot over bridge steel girder can be undertaken by qualified and tested welder under close supervision of experienced official to ensure that during repairs of cracked weld no member should be distorted due to application of excessive heat. Defective weld should be gouged out first and welding done with proper manipulation of electrode for homogeneity. Peening of weld is preferable for repairs of weld joint.

5.8 STRENGTHENING OF STEEL GIRDERS

These works are carried out only when steel girders are showing signs of distress during service life or when heavier loads are to be permitted than the designed load or speeds are to be increased. Strengthening is also required due to damages of component by external hit or on account of accidents on steel girders or loss of cross section due to heavy corrosion. All the strengthening works of open Web girder are very costly under traffic and therefore, they should be undertaken with careful check of design and planning for execution with the approval of Chief Bridge Engineer.

5.8.1 Steel girder of track bridge

a) Rectification measures for loss of camber in open web girder of track bridge is to be undertaken as prescribed in item 212 para 3 of Indian Railway Bridge Manual 1998.

b) Replacement of very loose rivets on account of oblonged holes by larger diameter rivets.

c) Replacement/strengthening of floor system on account of heavy corrosion and loss of steel section i.e. stringers and cross girders of through spans and top flange plates of underslung and plate girders.

d) Provision of cover angles and cover plates over the cracked members.

If heavy repairs are required to plate girders or strengthening of main truss of open web girders, it will be difficult to carry it out under traffic, hence spans are to be taken outside slewed with introduction of temporary girders for economical repairs.

If girder is quite old and residual life is only 10 years it is better to replace the old steel girder with new girder. Considering scrap value of old girder, replacement will be more economical than strengthening of existing girder under traffic. Fig 5.4 (a) and (b) shows some of the common method of strengthening of steel girders. However, any strengthening scheme shall be thoroughly analyzed and designed before using in field.

5.8.2 Road over bridge steel girder

Strengthening of web plates of plate girder of Road Over Bridge over corroded portion can be repaired with additional cover plates with rivetted joint. If possible, flange plate can be replaced with new flange plate or providing additional flange plate with rivetted joint. Stiffeners and footpath brackets can be replaced or repaired with cover plate with weld joints under close supervision by qualified welder to ensure that no distortion of member takes place during welding.

5.8.3 Foot over bridge steel girder

Strengthening of foot over bridge main girder-columns and staircase stringer can be undertaken by replacing member with new one or additional cover plate or angle with weld joints under close supervision by qualified and tested welder to ensure that no distortion of member takes place during welding. If floor beams or bottom lateral bracings are corroded or perforated, they can be replaced with new one instead of repairing them.

5.9 CASE STUDIES

5.9.1 Case study on - Replacement of Corroded/ Perforated Cross Girder at Bridge No. 136 on Delhi-Howrah Route

Kiul bridge was declared as distressed category II since 1999 and permanent speed restriction of 15 KMPH was imposed. Structural members of this bridge was showing sign of physical deterioration such as heavy corrosion/perforation and cracks at rail bearer, cross girders, bottom girders, bottom chords, cross bracings bottom lateral bracings, stringer top angles and loose/ corroded rivets at various locations Fig 5.5. (a) and (b). The salient features of the bridge is as under:

- Name of the River : Kiul River.
- Span : 2x9x45.7M (OMG)
- Between Kms : 420/17 to 421/11
- Between Stations : Kiul and Lukhisarai.
- Year of Construction : 1871 (Substructure)
- Year of Construction : 1910 (Superstructure)
- Type of Substructure : Brick Masonry.
- Type of Super Structure : Steel Girder (Through Type)



Fig 5.5. (a) Perforated top flange of cross girder



Fig 5.5 (b) Perforated web and bottom chord

This work was very specialized one because of through girder, electrified section and high traffic density. Therefore, to carry out all the rehabilitation activities, single line working was introduced during mega traffic as well as power block.

Major repair work for rehabilitation was planned by replacing members such as cross girders, Bottom Chord, Stringer Top Angles, Cross Bracing and Bottom Lateral Bracings. As per the drawings and the site

measurements, fabrication was done perfectly matching with the existing connection details.

For replacement of bottom chord before execution of the work, well equipped field workshop were established near the bridge and all the required material, tools and plants etc. for the fabrication and execution of work were arranged in advanced. For execution of these works several blocks (up to duration of 6 hours) were planned and a team of around 50 workers (including 5 fitters, 2 gas cutters, 6 riveters, 8 rigger and 25 helper) were deputed. Separate special gangs were provided for replacement of two cross girders at different locations with similar set up parallel during mega block. The tools and plants are given in Table:5.1. Besides these other main materials and arrangements are listed in Table:5.2. The safety measures adopted are shown in Table:5.3.

Table : 5.1 List of Tools and Plants.

S. No	Tools & Plants	Nos.
1	Differential pulley blocks a) 3 tones capacity b) 5 tones capacity	 03 03
2	Hydraulic Jack a) 20 tones b) 30 tones a) 50 tones	 02 02 06
3	Straightening Machine	02
4	D.G. Set (33 KVA)	01
5	Welding Machine	01
6	Drifts	200
7	Hammer (Different capacity)	16
8	D.H. Spanner	12

Table Contd...

Table: 5.1 Continued from Previous page

S. No	Tools & Plants	Nos.
9	Pneumatic machine a) Drill b) Riveting machines.	 2 2
10	Sling (wire rope)	12
11	Air compressor machine with complete accessories	02
12	Gas cutting set	02
13	dip lorry	02 sets
14	Turn bolts	100
15	Service bolts 200 nos.	200
16	Turn buckle	4
17	CC cribs with nuts & bolts	100
18	Rivets 20mm, 22mm dia. of various lengths.	

Table: 5.2 Minor material and arrangements.

S.N.	Tools & Plants
1	Scaffolding.
2	CC Crib with clamps.
3	Wooden Blocks of different size.
4	Manila rope of different length.
5	Wooden planks.

S.N.	Tools & Plants
6	Sleepers.
7	G.I. Pipes, Hose Pipe, etc.
8	Other Small tools – row bars of different sizes.
9	Fuel Grease and other Oils.
10	Grinding Machine.

Several safety measures were taken during the execution of works, same are shown in Table: 5.3

Table: 5.3 Safety measures

S. No	Safety measures
1	Checking of scaffolding
2	Checking up of all tools & plants
3	Protection of track
4	Provision of safety helmets; belts
5	Provision of first aid facilities at site
6	Provision of road vehicles at site
7	Provision of dedicated communication system between the team members and supervisory authority.

The entire work was divided into Pre Block, During Block and Post Block activities. The details of activities are given in the Tables: 5.4, 5.5 and 5.6.

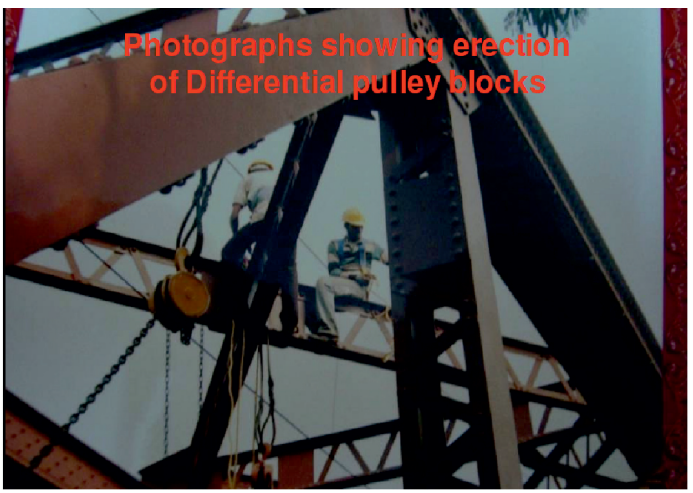


Fig 5.6 Photographs of erection of differential pulley blocks.

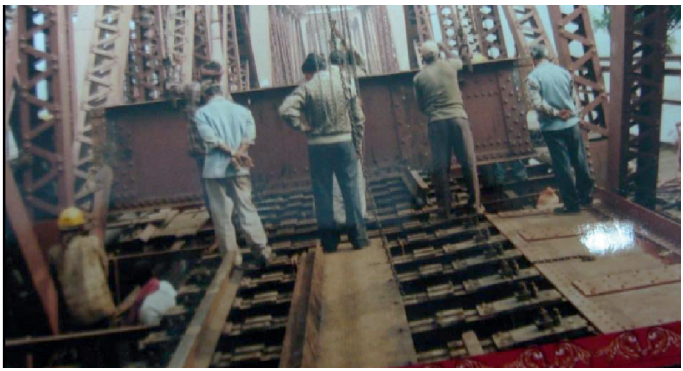


Fig 5.7 Dismantling and taking out of cross girder.



Fig 5.8 Placement of newly fabricated cross girder.



Fig 5.9 Structure after replacement of new cross girder and fixed with new rivets.

Table: 5.4 Pre block activities

S.N.	Block Activity
1	Erection of scaffolding.
2	Cutting of rivets in bottom main angles of X-girder and replaced by Bolts & Drifts
3	Cutting of 50% rivets in joints between X- girder & rail bearer & replaced it by Bolts & Drifts.
4	Cutting of 50% rivets in joints cleat angle of X- girder with verticals of truss on both ends & replaced it by Bolts & Drifts.
5	Loosening of hook bolt of channel sleepers & rail cleats, of running rail, guard rail & opening of chequered plate.

Table: 5.5 During block activities

S.N.	Activities	Time
1	Shifting of fabricated x-girder to the erection site in dip lorry & kept it on a suitable position & shut down of OHE connection with D/rod.	75 minutes
2	Erection of 6 nos chain pulley block of 3 Ton capacity etc, 4 nos at the end of rail bearers and 2 nos at the end of X-girder for keeping the rail bearer in position & dismantling/erection for X-girder respectively. (a) Cutting of rest 50% rivets in joints between X-girder and rail bearer and punching out by rivets busters. (b) Cutting of rest 50% rivets in joints cleat angle of X-girder with verticals of truss on both sides & punch out.	
3	Removing of 4 nos rail (2 nos running rail & 2 nos guard rail) of different length by making free from channel sleeper. The dismantled rails have to be shifted to a location nearer the working area should be free from sleeper and chaqured plate.	
4	Holding the X-girder & rail bearers with chain pulley blocks including debolting all the bolts and taken out the existing X-girder with the help of chain blocks & kept in a suitable location.	90 minutes
5	Placing of new X-girder in position with the help of chain pulley blocks without the bottom angles and jointing with bolts. Then bottom angles of X-girders is fitted with Turn bolts & drifts.	90 minutes
6	Refitting of dismantled track in existing position over channel sleepers.	105 minutes

Table Contd...

Table : 5.5 continued from previous page

S.N.	Activities	Time
7	Shifting of dismantled X-girder to the nearer railway stock yard with the help of dip lorry.	
8	Riveting in joints of X-girder to verticals and rail bearers (at least 50%) & balance 50% on Turn bolts & drifts.	
9	Removing of chain pulley blocks and other tools & tackles from the bridge site. Then the Traffic & Power block removed & bridge is open for the traffic with SD & 10 Kmph for 1st train	

Table: 5.6 Post block activities

S. N.	Block activity
1	Turn bolts& drifts are to be replaced by rivet one by one after opening of the same.
2	Temporary support to the member should be removed.
3	Released member to be carried to scrap yard near to site.
4	First train allowed with stop dead & 10 Kmph & subsequent trains @ 15 Kmph

5.9.2 Case study on - Replacement of bottom cord member and strengthening of the girder of road over bridge at Katihar yard.

Mangal Bazar Road Over Bridge was constructed in 1064, having Span 1 x 45.759 m + 2 x 12.2 m (Plate

Girder), with RCC deck slab in Katihar yard. Total wt of girder is around 400 tons (Steel - 200 tons + RCC slab-187 Tons + Foot path wt- 13 tons).

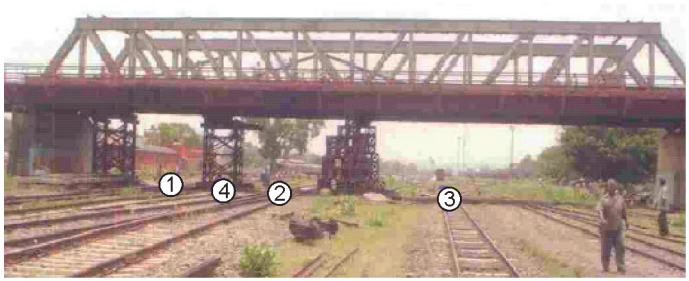


Fig. 5.10 Katihar ROB crossing - 3 BG and 4 MG lines

During inspection it was found that L_0- L_3 member of bottom chord , joints of cross girder and bottom cross bracing were badly corroded, which is evident from Fig. 5.11 and Fig. 5.12



Fig. 5.11 Bottom chord and cross bracing member badly corroded



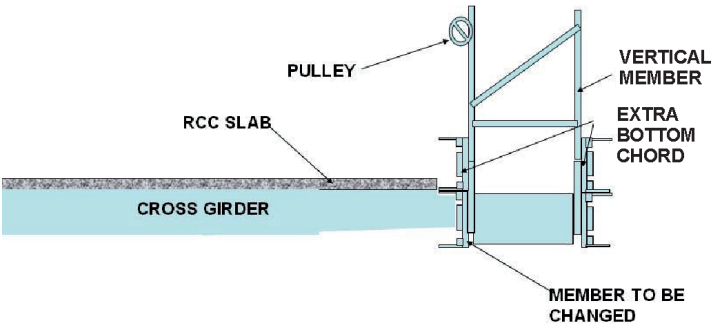
Fig. 5.12 Bottom chord severely corroded and eaten up

After thorough inspection, material requirement was assessed. It was estimated that for replacement girder members about 20 t of steel will be needed while for strengthening purpose about 19 t of steel will be needed. For carrying out the work following detailed drawings were prepared.

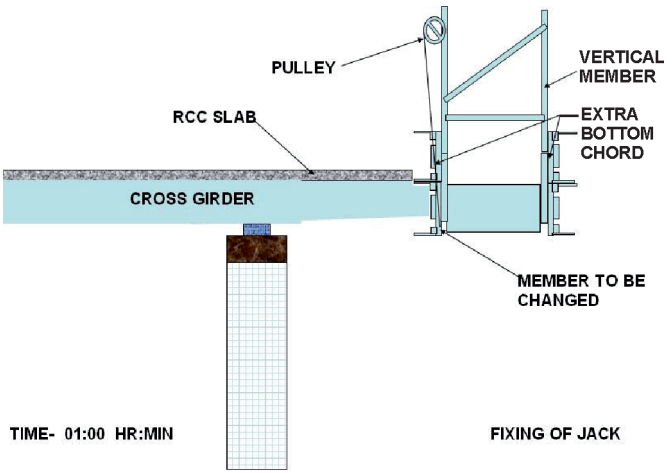
Table: 5.7 Various drawings used for work

1	Temp arrangement drawing	Drawing No. B/38/2004
2	Repairing of Pathway	Drawing No. B/38/2004
3	Additional Bottom chord to be provided in KIR station end	Drawing No. B/11/95
4	Repairing / replacement of Bottom Chord, Gusset, Cross Girder	Drawing No. B/08/2007

Application to CRS was sent along with all drawing for CRS sanction. CRS / Kolkata has accorded sanction that - (i) Work to be taken up and executed by Bridge Organization and (ii) Work shall be executed with all due care and precautions so as not to jeopardize the safety of road or rail operations.

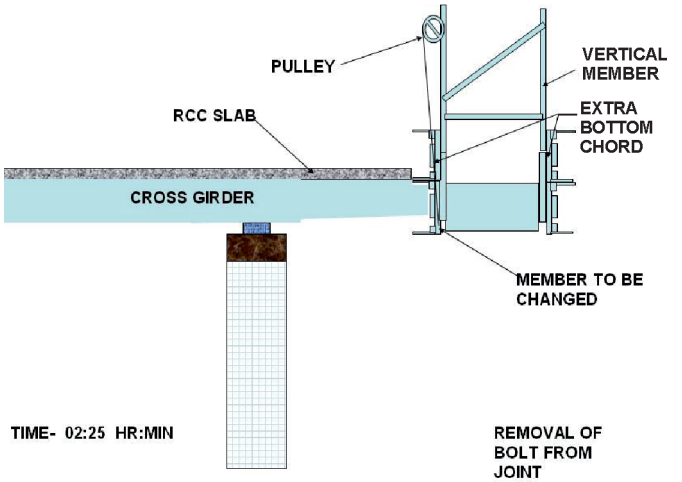


Activity - 1

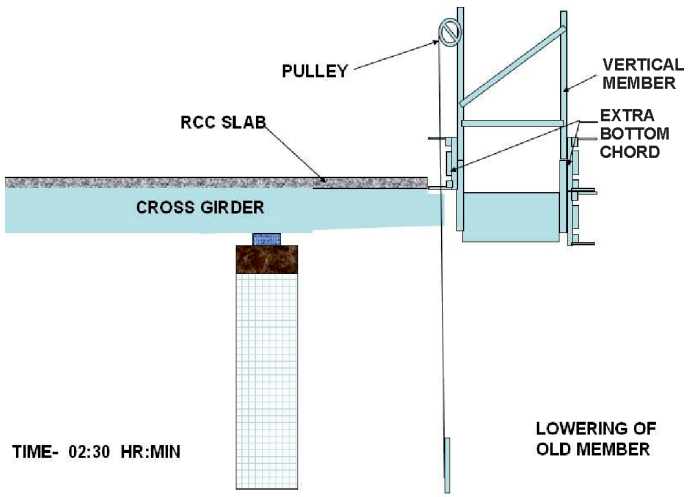


Activity - 2

Fig. 5.13 (a) Schematic activity during 6 hr block planning

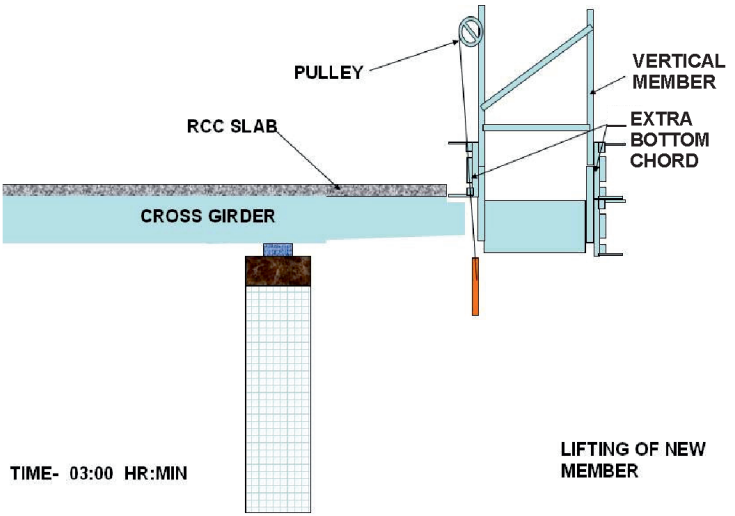


Activity - 3

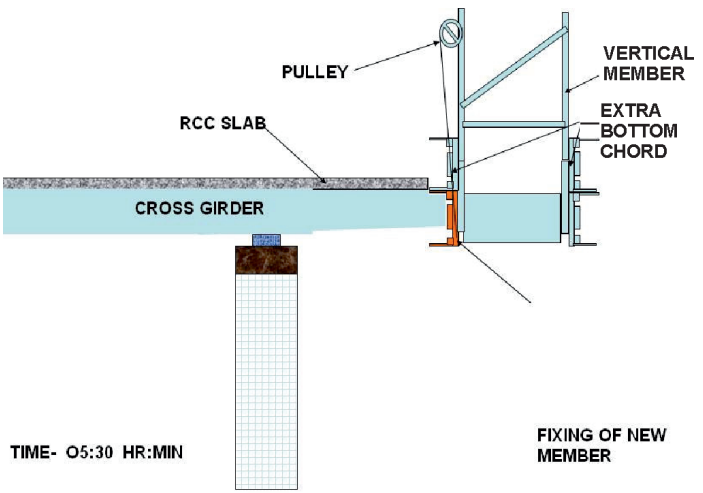


Activity - 4

Fig. 5.13 (b) Schematic activity during 6 hr block planning

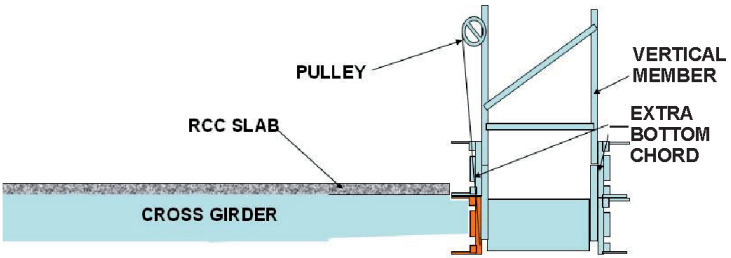


Activity - 5



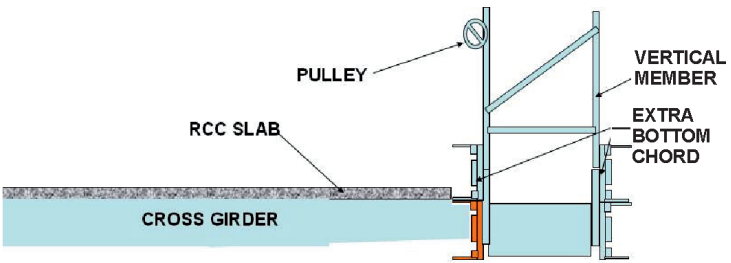
Activity - 6

Fig. 5.13 (c) Schematic activity during 6 hr block planning



TIME- 6:00 HR:MIN

Activity - 7



BLOCK CLEAR

Fig. 5.13 (d) Schematic activity during 6 hr block planning

Methodology used for replacement of bottom boom -

(i) Supporting the cross girder no.1, 2, 3, from bottom as the cross-girder to bottom connection was required to be opened.

(ii) Replace inside vertical bottom chord plate.

(iii) The bottom boom was replaced by changing component one by one. The step included:-

a) New member was fabrication of same size.

b) For proper hole matching Templates, were made by taking actual measurement from existing member.

c) All rivets of bottom boom (L_0 - L_4 inside) were cut one by one and service bolts provided.

d) Traffic block of 6 hrs is obtained.

e) After supporting cross girder with CC cribs service bolts were removed.

f) Corroded plate was lowered with rope pulley arrangement.

g) Newly fabricated member was lifted and before fixing one coat of Zinc Chrome red oxide priming was applied on the contract surface and hidden surfaces.

h) Tightening of service bolt.

i) After complete erection, riveting work was done.

j) After completion of the work painting done.

Activities related to replacement of bottom chord are detailed as follows:-

Pre block activity -

1. Erection of temp supports as per plan no B/38/2004.
2. Side path way was removed to facilitate replacement of extra bottom girder.
3. Extra bottom chord over the badly corroded member was provided as per Drawing No. B/11/95.
4. New bottom chord, gusset, Cross Girder were fabricated as per Drawing No. B/08/2007, steel used confirming to IS 4076 Grade-B.
5. Sufficient working space between inner bottom chord and RCC slab was not available, therefore, 3 " slab was cut manually for a length of 13 meter and exposed reinforcement was clean and repaired with 1:3 cement mortars.

Table: 5.8 Detailed block planning inner bottom chord plate (L_0- L_3)

Activity No.	Activity	Duration
1	CC cribs were erected on passenger line and jacking arrangements were made to support L2 cross beam.	60 min
2	Removal of service bolt from joint connection gusset and cross beam	75 min
3	Lowering of old member	15 min
4	Lifting of new fabricated member	20 min
5	Fixing of new members including fixing of service bolt	150 min
6	Removal of CC cribs from passenger line	25 min
7	Total hrs.	6.00 hrs.

Table: 5.9 Block planning for changing of outer plate of bottom chord plate (L_0 - L_3)

Activity No.	Activity	Duration
1	Removal of service bolt from joint connection gusset and cross beam	75 min
2	Lowering of old member	15 min
3	Lifting of new fabricated member	20 min
4	Fixing of new members including fixing of service bolt	150 min
5	Clearing of traffic block	
6	Total hrs	4.30 hrs

Post block Activity -

1. Riveting :- After replacement / repairing member riveting work was done, 20 mm dia rivets were used.
2. Painting :- After completion of the work of strengthening member were painted with two coat of red oxide.



Fig. 5.14 (a) Side view of replaced bottom chord



Fig. 5.14 (b) Strengthening of cross girder

Precaution Taken -

1. Heavy vehicle movement was restricted during riveting work.
2. For whole matching template were used.
3. Painting of hidden surface and contact member were done.
4. During riveting work, GI sheet were used below cross girder.

5. Special treatments was given member below RCC slab as inspection and painting is very difficult.

5.10 SUITABILITY OF EXISTING BGML / RBG / MBG & HM LOADING FOR OWG TO 25 T LOADING

Suitability of bridge drawing for BGML , RBG, MBG and HM loading for "25t loading-2008" has been issued vide RDSO's letter of even no.27.03.2009. RDSO has further carried out analysis to identify the members where stresses are 95-100% and 100-105% of permissible values. The details of analysis are given below:-

Table: 5.10 Members of various girders expressing over stressing due to higher loading standard.

Loading / Span	Drg. No.	Members
BGML		
30.5 m Under slung	BA-11232	L_1- L_2
45.7 m Open web	BA-11102	L_0- L_1
76.2 m Open web	BA-11152	L_1-L_0, U_1-U_2, U_3-U_4, U_4-U_5
RBG		
45.7 m Open web	BA-11362	U_1-U_2, U_2-U_3, L_0-L_1, L_3-L_4
61.0 m Open web	BA-11322	U_1-L_2
76.2 m Open web	BA-11382	L_2-U_3 U_3-U_4, U_1-L_2, U_4-U_5, L_0-U_1

As per Steel Bridge Code, clause 3.20.2, overstressing in open web girder up to 5% of permissible value is permitted subject to bridge being kept under regular observation. Members of bridges which are having stress ranging from 95-100% as indicated above, may also be observed during inspection. Railway may like to identify these members by giving a suitable paint mark for easy identification during inspection.

For field identification of these members, there should be three yellow bands of suitable width (say 10 cm), so that bands are clearly visible on the identified members e.g. one yellow band on the identified member near each of nodal points and one in the middle.

■ ■ ■

REFERENCE

BS - 111 (2016)	Guidelines for use of High Strength Friction Grip (HSFG) bolts on bridges in Indian Railways.
BS – 45 (2004)	Guidelines on Fabrication of H – Beam steel sleepers suitable for welded plate girder.
BS – 1475 (1972)	Specification for Wrought Aluminum and Aluminum alloy for general engineering purpose – wire.
BS – 2451 (1963)	Specification for chilled iron shot and grit.
Bridge Standard Committee – 82	Item No. 1046, c/s indicating conditions to carry LWR over girder bridge.
BS – 90 (2008)	Study onprobable cause of cracks in different members and assessment of Residual Fatigue Life of Bridge No. 46 Up/Mid Line near Bilaspur.
Case Study	Integrated Course No. 12102, Failure of welded steel plate girder (Cracks noticed over the web and position of the crack below the top fillet weld in 3 girders.
Case Study – Bridge No. 586 (2010)	Assessment of residual fatigue life of bridge no. 586, near Koraput, East Coast Railway.
Case Study – Bridge No. 136	Replacement of corroded perforated cross girder of Kiul bridge on Delhi Howrah route.
Case Study – Bridge at Katihar yard	Replacement of bottom cord member and strengthening of the girder of road over bridge at Katihar yard.
IRS-P 31	Specification for zinc Chromate Red Oxide primer.
IRS-M-28 class A-2 or C-1	Specification of Electrodes for CO2 welding.

IRS-M-46 (2001)	Specification of wire for CO2 welding.
IRS-Steel Bridge Code (2003)	Design of steel and wrought iron bridges.
IRS-Welded Bridge Code (2001)	Metal Arc welded in mild steel bridges.
IRS-Specification B1 (2008)	Indian Railway Standard Specification for Fabrication, erection and maintenance of steel girders and locomotive turn tables.
IRS T-10	Specification for plain washer, taper washer, single coil spring washer for bolt to fix SGCI Bearing plate.
IRS T-31 (1992)	Specification for Elastic Rail Clips Mk-III
IRS T-46 (1990)	Material for SGBP
IRBM (1998)	Indian railway Bridge Mannual
IS – 5 (2007)	Indian Standard Colours for Ready mixed paints and enamels
IS – 739 (1992)	Indian Standard wrought Aluminum and Aluminum alloy-wire for general engineering purposes specification.
IS – 104 (1991)	Indian Standard specification for ready mixed paint Zinc Chrome priming
IS – 508 (2007)	Indian Standard Specification for General Graphited.
IS – 549 (2005)	Indian Standard Specification for split pins.
IS – 1148 (2009)	Indian Standard Steel rivet bars (Medium and High tensile) for structural purpose.
IS – 1149 (2005)	Indian Standard Specification for High tensile rivet bars for structural purpose.
IS – 1363 (2002)	Indian Standard Hexagon head bolts, screw and nuts of product grade 'C'
IS – 1367 (Part XII) (1981)	Indian Standard Technical supply condition for threaded steel fastens. Phosphorous coating

	threaded fastens.
IS – 1367 (Part XII) (1983)	Indian Standard Technical supply condition for threaded steel fastens. Hot dip galvanized coating on threaded fastens.
IS - 1387 (1993)	General requirement of metallurgical Materials.
IS – 1745 (1978)	Specification of Petroleum Hydrocarbon solvent.
IS - 1852 (1986)	Specification for Rolling Tolerances for Hot Steel products.
IS 1865 (1991)	Indian Standard Iron Casting with spheroidal or modular graphite – specification.
IS – 1893 (2002)	Indian Standard criteria for earthquake resistant design of structure.
IS – 2062 (2011)	Indian Standard Hot rolled medium and higher tensile structural steel – specification.
IS - 2074 (1971)	Indian Standard air drying, red oxide ready mixed paint – specification.
IS – 2339 (1971)	Indian Standard Specification for aluminum paint for general purpose, in dual container.
IS – 2629 (1997)	Indian Standard Recommended practice for Hot dip galvanizing of Iron and Steel.
IS – 3063 (2004)	Indian Standard fasteners – single coil rectangular section spring lock washers – specification.
IS – 3757 (1989)	Indian Standard Specification for higher strength structural bolts.
IS – 4000 (1992)	Indian Standard High strength Bolts in steel structure – Code of practice.
IS 4076 (1997)	Indian Standard Specification for brass wires for springs and other special purpose.
IS – 4759 (2006)	Indian Standard Hot dip zinc coating structural steel and other allied products – specification.
IS – 5666 (2009)	Indian Standard Specification for Etch

	(Pretreatment) Primer.
IS – 5909	Surface roughness in accordance with Appendix 'A'
IS – 6623 (2004)	Indian Standard high strength structural nuts – specification.
IS – 6649 (1988)	Indian Standard Specification for hardened and tempered washers for high strength structural bolts and nuts.
IS – 8500	Indian Standard Specification for high tensile steel (equivalent to IS 961 old)
IS - 8910 (2010)	General Indian Standard technical and steel product.
IS – 9954 (2000)	Indian Standard pictorial surface preparation for painting of steel surfaces.
IS – 13607 (1992)	Indian Standard ready mixed paint, finishing, general purpose, synthetic – specification.
RDSO DRG. B-1528 / 1 9.14 m	span welded plate girders with riveted lateral bracing
RDSO DRG. B-1636 and 1636/1	Steel Channel Sleeper drawing
RDSO DRG. B-1636/R2 & 1636/1/R2	Revised steel channel sleeper drawing
RDSO DRG. B-1636/2	Increased hight of steel channel sleeper
RDSO DRG. B-1636 / 5	ISHB (Length of sleeper i.e H - Beam steel sleeper)
RDSO DRG. B-1636 / 8	ISHB-200 suitable for welded plate girders / stringers H - Beam steel sleeper
RDSO DRG. B-6081	30.50 m Underslung span
RDSO DRG. B-11754 / 3 R1 & 2 R1	Welded type Composite girder for 30.5 m span
RDSO DRG. BA-1057	18.3 m span of BGML loading
RDSO DRG. T-3701	Elastic Rail Clip Mk-III

RDSO DRG. T-5155 to 5164	Rail fastening arrangement on BG for 60 kg running rail and 52 kg guard rail
RDSO DRG. T-5163	6 mm thick Grooved Rubber Pad for Guard rail
RDSO DRG. T-5164	Bolt and Nut for Guard rail
RDSO DRG. T-5197 to 5200	Rail fastening arrangement on BG for 52 kg running rail and 52 kg / 90 R guard rail
RDSO DRG. T-7010	Rail pad 10 mm thick Composite Grooved Rubber Sole Plate
RDSO DRG T-8353 & T-8353 / 1	MS Taper washer & Plain Washer for Special Bolt at bottom of top flange of H-Beam on Girder Bridge
RDSO DRG. T-8391	Rail seat assembly for Rail Free Fastening System for 60 Kg (UIC) Rail on H-Beam Steel Sleepers for Girder Bridge BG
RDSO DRG. T-8392	SGCI Bearing plate for Rail FreeFasteningSystem for 52 Kg / 60 Kg (UIC) Rail on H-Beam Steel Sleepers for Girder Bridge BG
RDSO DRG. T-8393	SGCI special Liner for Rail free fastening system for 60 Kg (UIC) Rail on H-Beam Steel Sleepers for Girder Bridge BG
RDSO DRG. T-8394 & T-8394 / 1	High Density Polyethylene Pad below SGBP plate & between Rail and Rail pad for Rail Free Fastening System for 60 Kg (UIC) on H-Beam Steel Sleepers for Girder Bridge BG
RDSO DRG. T-8395 & T-8395 / 1	25 mm Ø Special bolt and Lock nut for Rail Free Fastening System for 52 Kg/60 Kg (UIC) Rail on H-Beam Steel Sleepers for Girder Bridge BG
RDSO DRG. T-8396	Rail seat assembly for Rail Free Fastening System for 52 Kg Rail on H-Beam Steel Sleepers for Girder Bridge BG

RDSO DRG. T-8397 & 8398	Manufacturing of SGCI Liner for Rail Free Fastening System for 52 Kg Rail on H-Beam Steel Sleepers for Girder Bridge BG
RDSO DRG. T-8399	30 mm thick packing plate for Rail free fastening System for Guard rail for H-Beam Steel Sleeper for Girder Bridge BG
RDSO / M&C/PCN-102/86	Epoxy Zinc phosphate primer
RDSO / M&C/PCN-103/86	Epoxy micaceous iron oxide
RDSO / M&C/PCN-109/88	Polyurethane red oxide
RDSO / M&C/PCN-110/88	Polyurethane aluminium
RDSO / M&C/RP-197 / 03	IRS Specification for 25 mm thick Nylon Cord Reinforced Elastomeric Pad
RDSO / M&C/RP-200/2007	Specification for Rail pad composite GRSP
RDSO Specification BS-45	Specification for fabrication of H-Beam Steel Sleepers
RDSO Report No.CT-32 (Rev.1)	Details of Zero toe load fastener
RDSO Report No.135 - 45 (May2004)	Guide lines for fabrication of steel channel sleepers
SSPCPT - 3 53T	Finishing coat of painting, first coat shall be wash primer of this specification

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