DESIGN ASPECTS OF THE PRECAST PRETENSIONED U-GIRDER BRIDGE FOR METRO RAPID TRANSIT SYSTEM

A Project Report

Submitted by

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ROLL NO. 2K13/STE/25

In partial fulfilment of the requirement

for the award of the degree of

MASTER OF TECHNOLOGY

In

STRUCTURAL ENGINEERING

Under the guidance of

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CERTIFICATE

This is to certify that this project report entitled **"DESIGN ASPECTS OF THE PRECAST PRETENSIONED U-GIRDER BRIDGE FOR METRO RAPID TRANSIT SYSTEM"** being submitted by me towards partial fulfilment of the requirement for the award of the degree of Master of Technology (Structural Engineering) is a work carried by me under the supervision and guidance of Associate Professor Sh. Alok Verma.

The matter embodied in this project has not been submitted for the award of any other degree and free from plagiarism.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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DECLARATION

I hereby declare that

a. The work contained in this report is original and has been done by me under the guidance of my supervisor.
b. The work has not been submitted to any other Institute for any degree or diploma.
c. I have followed the guidelines provided by the University in preparing the report.
d. I have confirmed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.
e. Whenever I have used materials (data, theoretical analysis, figures and text) from other sources, I have given due credit to them by citing them in the text of the report and giving their details in the references.

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ACKNOWLEDGEMENT

I take this opportunity to express my deep gratitude to all those people who have extended their cooperation in various ways during the course of this study. It is my pleasure to acknowledge the help of those individuals.

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I would like to thank my employer Vayam Technologies Ltd. and my reporting officer Mr. Mahender Vashist to provide me sufficient time for working on my project.

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ABSTRACT

Bridges are the utmost important part of human life and their requirements are increasing day by day in various aspects. Safety of life is the prime consideration for design and construction of bridges.

For example, as in the field of tall buildings, different structural systems are required for different heights. Similarly, in the field of bridge engineering special type of bridge is required for depending upon the span length. Slab type, hollow slabs and RCC T-beam bridges are preferred for smaller spans while box and truss type bridges are preferred for longer spans. This is due to their increased moment of inertia. But due to the increased depth of these structural systems overall height of the bridge is also increased to maintain the vertical clearance below deck slab. Thus, a separate study and comparison of various bridge types are required based on their application so as to make use of the most efficient structural system.

This project report is prepared by studying the various design aspects of U-Girder bridges applicable for Metro Rapid Transit System (MRTS). The main advantage of the U-Girder bridges are reduction in the height, weight and time of construction of the superstructure so as to decrease the overall cost of the project. 2m depth of segmental box type of bridge is replaced by 250mm (approx.) thick deck slab of U-Girder, reducing the height of every pier by 1.75m.

Longitudinal analysis is carried out to calculate the amount of prestressing required and transverse analysis is carried out to calculate the amount of reinforcement required. The section for U – Girder is taken from the standard drawings of DMRC for U-Girders.

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CHAPTER 1 : INTRODUCTION

1.1 Introduction

The U-shaped girder bridge (also called 'Channel Bridge' and 'C-Girder') is a relatively new and innovative concept in bridge deck design. U-shaped girder is appropriate when a new or modified alignment structure requires an increase in the vertical clearance beneath the bridge. The bridge deck made of prestressed concrete (PSC), has other important advantages, such as reduced construction time, aesthetic appearance, durability and economy. This concept can be used for overpasses, under-crossings, viaducts, etc.

Two separate sets of U-girders make one segment of the viaduct, with each girder being the up and down line. A considerably larger work space is needed to use U-girders, along with extra machinery.

Figure 1.1 A Typical Twin U – Girder Viaduct

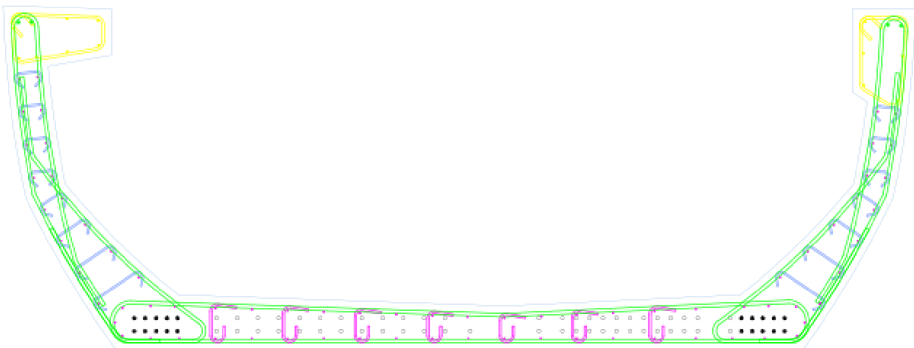


Figure 1.2 Schematic Representation of a Typical U - Girder

To erect one viaduct segment, two cranes have to launch either sets of the U-girder and a wider pier cap is also required to place the bearings.

1.2 Objective of the study

The objective of this project report is to study the various design aspects of the U-Girder Bridge and the level of their suitability for Metro Rapid Transit System. Advantages and disadvantages of U-Girders compared to other conventional systems.

The present report has the following objectives:

1. To study on the application of U-Girders for MRTS (Metro Rapid Transit System)
2. Method of Construction and construction sequence
3. Merits and demerits of using U Girder over other conventional systems.
4. Longitudinal analysis of the U – Girder to determine the amount and pattern of prestressing so as to control the fiber stresses within the permissible limits at every stage of construction.
5. Transverse analysis of the U – Girder to calculate the amount of reinforcement required in deck slab in transverse direction.
6. Validation of design with standard drawing available by DMRC for respective span.

1.3 Scope of the study

The present report is restricted to analysis and design of a typical span of 27m and 16t axle loading. For this 2D and 3D analysis are performed using Staad pro v8i and excel spread sheets. Casting yard of CEC at Greater Noida was visited by me to understand the complete procedure of casting and the sequences in casting of U - Girders. I also visited the construction sites to understand the methods of erection.

1.4 Methodology

1. A thorough literature review to understand the behavior of U - Girders.
2. Selection of a typical span of 27m and 16t axle loading with geometrical properties and structural detailing same as that of standard drawings provided by DMRC at tender stage. U – Girder with Standard gauge of 1436mm is chosen for the study.
3. Longitudinal analysis is carried out using IRC: 18 – 2000 Design Criteria for Prestressed Concrete Road Bridges and IRC: SP: 71 – 2006 Guidelines for Design and Construction of Precast Pretensioned Girders for Bridges, to calculate the amount of prestressing required.
4. Transverse analysis is carried out using Staad pro v8i in 2D as well as in 3D.
5. The results are validated with the standard drawings made available by DMRC for respective span.

CHAPTER 2 : LITERATURE REVIEW

The literature available on the behaviour of U – Girders is very limited; however we can get a number of published literatures on the analysis of Pre-stressed girders of different shapes like I – Girders. Thus the literature survey is presented here on the basis of some available papers.

Prof. Devdas Menon [1] has analysed the behaviour of U – Girder bridge decks. The concept of U-shaped bridge girder is now being increasingly adopted in urban metro rail projects and for replacing old bridges where there is a constraint on vertical clearance. These bridge decks are commonly designed in practice using simplified methods that assume beam action of the webs in the longitudinal direction and similar flexural action of the deck slab in the transverse direction. However, such assumptions can lead to errors. Therefore he attempts to assess the extent of error in the simplified analysis, by comparing the results with a more rigorous three-dimensional finite element analysis (3DFEA). A typical prototype railway bridge girder was taken as a case study. The results of the 3DFEA, in terms of load-deflection plots, was validated by field testing. The evolution of U – Girders is also summarised with their references and explained its concept.

Jose Ma. Rioboo Martin. [2] Published a paper on precast prestressed concrete bridges for congested urban areas. A case study was done on twin precast pretensioned concrete bridges over Tlalpan freeway in one of the Maxico city's most congested area. Three girders were used having maximum span of 52m. Main significance was the innovative structural solution using continuous hollow girders that permitted a lower section and thereby a reduced cost.

Final detailed project report of Pune Metro Rail Project by DMRC for Pune Municipal Corporation [4] explains the need and advantages of Metro Rapid Transit System. In section 5.12.4, the factors to choose a structural system are explained. Type of superstructure for elevated sections are compared under two heads –

A. Pre-cast segmental box girder using external unbounded tendon.
B. Pre-cast segmental U-Channel Superstructure with internal pre-stressing.

Segmental box is simplification of all post-tensioning operations, especially installation of tendons. Replacement of tendons in case of distress is possible and can be done in a safe and convenient manner. Good corrosion protection due to tendons in polyethylene ducts; the grout inspection is easier and leaks, if any, can be identified during the grouting process.

U – Girder adopted here, is simply a precast pretensioned girder having a special shape to meet the requirements of Metro rapid Transit System. The procedure for the analysis and design of U – Girders is similar to that of I-Girders. Care should be taken to assess the type and amount of loading on U – Girders. To get the values of various type of loads acting on U – Girders Design Basis Report of DMRC is adopted.

IRC: SP: 71 – 2006 [9] gives the various Guidelines for Design and Construction of Precast Pretensioned Girders for Bridges. All the prestressing losses are calculated in accordance with this code at every stage of construction.

IS: 14268 – 2003 [10] has been adopted to get the properties of high tensile steel being used for prestressing in U – Girders. Uncoated Stress Relieved Low Relaxation Seven Ply Strand of class 2 are used.

IS: 456 – 2000 [12] is used to calculate the flexure reinforcement from ULS combinations. Also crack width and stresses in steel and concrete are calculated in accordance with clause 35.3.2 and 43.1 of this code.

IRS Concrete Bridge Code: 1997 [7] limits the values of permissible stresses by 0.75fy in steel and 0.4fck in concrete.

T. Y. Lin [6] explains the development of building materials from stones, bamboos and timbers to prestressed concrete. Has formulated the calculated of prestressing losses. All the formulae prepared by me for this project report are taken from T.Y. Lin following the restriction of provisions made through various codes mentioned in reference.

CHAPTER 3 : STUDY ON U - GIRDER

3.1 U – Girder Bridge Concept

Structurally, the U-shaped girder bridge can be viewed as the conventional ‘single-cell box girder’ with its top flange removed, as shown in Fig. 1. The two webs are configured as beams positioned above and on either side of the deck surface. The webs and the deck slab are pre-stressed with suitable profile of longitudinal strands/tendons. The longitudinal stiffness and strength are obtained from the two webs as well as the connecting passageway slab spans between the webs. The resulting requirement for the depth of girder section below the passageway level is very less than that required for convectional beam-and slab type designs, as shown in Fig. 2, and herein lies its main functional advantage.

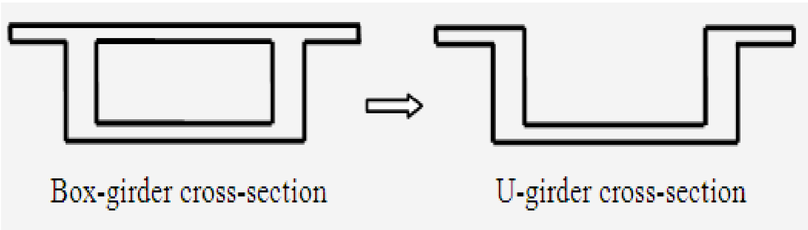


Figure 3.1 U Shaped Girder vs. Box Girder

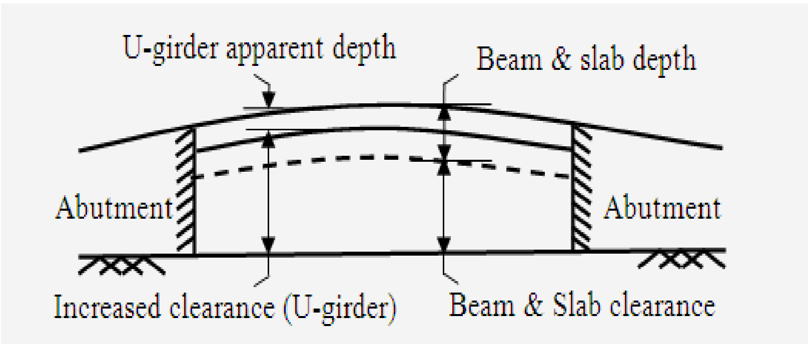


Figure 3.2 Comparison of U – Girder concept with conventional “Beam and Slab” construction

The U - girder is essentially a ‘through’ type girder where the train passage occurs on the soffit slab; the side cantilevers serve as ‘keyman’ pathways for maintenance, emergency exit and to place OHE (Overhead equipment) masts.

Figure 3.3 A Typical Through Type Bridge

3.2 Development to Prestressed Concrete

- In **reinforced concrete**, concrete and steel are combined such that concrete resists compression and steel resists tension. This is a **passive combination** of the two materials.
- In **prestressed concrete** high strength concrete and high strength steel are combined such that the full section is effective in resisting tension and compression. This is an **active combination** of the two materials. The following sketch shows the use of the different materials with the progress of time.

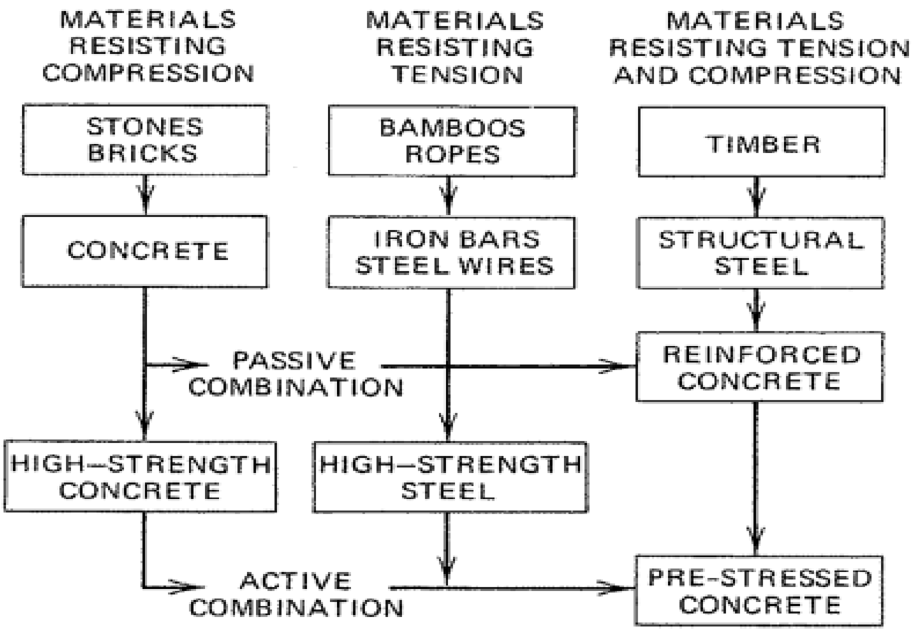


Figure 3.4 Development of Building Materials

3.3 Evolution of 'Channel Bridge'

The precast segmental concrete "channel" or "U - shaped" bridge was first developed by Jean Muller in 1990s for the Champfeuillaet Over pass Bridge in France. Subsequently, in the mid-1990s, there was an extensive research evaluation programme carried out in USA by the Highway Innovative Technology Evaluation Centre (HITEC). Between 2001 and 2003, the Sorell Causeway Viaduct was built in Australia. It became the first channel bridge viaduct built in the world.

The specialist rail consultancy firm, Systra, has developed a precast prestressed concrete U-shaped type bridge based on the original channel bridge constructed in France. The Wodonga Rail Bypass project in Austria, designed by Systra uses a simplified U-shaped bridge concept as shown in Fig.

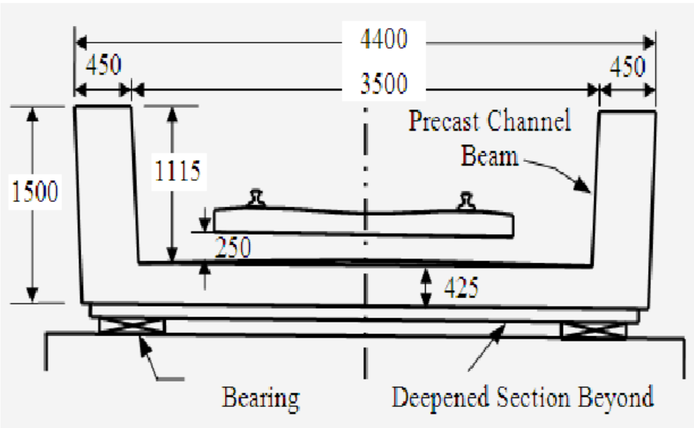


Figure 3.5 Cross – section for Wodonga Rail Bypass in Austria

An international patent has been taken for this concept by Systra.

3.4 Common Type of Standard Span Superstructures, used for Metro Construction in India

Following types of standard span superstructures have commonly been used for metro construction in India:

Figure 3.6 Box Girder Supporting 2 Tracks – Precast Segmental

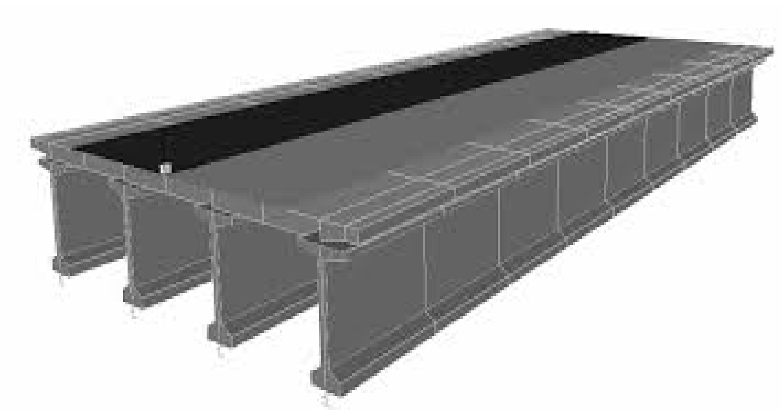


Figure 3.7 I - Girder (Precast) with Cast-In-Situ Slab

Figure 3.8 U - Girders supporting 2 Tracks – Precast Segmental

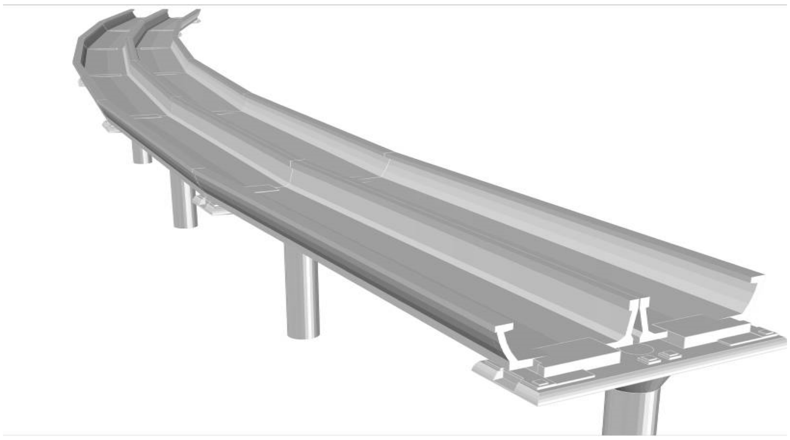


Figure 3.9 U - Girder supporting Single Track – Full Span Precast Girder

3.5 Application of U - Girder in India

- U Girder was proposed by Systra in India for the purpose of MRTS (Mass Rapid Transit System). It can also be used to replace the old bridge where there is a requirement of increased vertical clearance.
- **In India, first time it was used in the airport metro express line.**
- Thereafter, it was used in Mumbai Metro line - I.
- Thereafter, segmental post – tensioned U-Girder was used in a long stretch in Noida - Dwarka line.
- Recently it was used on entire Badarpur-Faridabad corridor of Delhi Metro where an incredible 1.2km of the viaduct was built in a month, making it one of the fastest corridors being built in Phase III of DMRC.
- Thereafter it was proposed in Kochi Metro where Aegis India Ltd. is the detailed design consultant.
- Thereafter it was proposed in Lucknow Metro.
- Now it has been proposed in all the three packages NC 01, NC 02 and NC 03 of Noida – Greater Noida Metro Line. Extension of Dilshad Garden to Ghaziabad. Also it has been proposed again in Mumbai Metro Line – II and several coming projects.

3.6 Merits of U - Girder

- Reduced formation level and thus reduced approach length.
- Built-in structural elements capable to maintain the trains on the bridge in case of derailment (a standard barrier known as parapet design allow this).
- The top flange acts as part of platform slab at stations and as an evacuation walkway from trains in-between station.
- Construction is rapid.
- Aesthetically good.
- Economical as compared to conventional design.

3.7 Demerits of U - Girder

- The erection of these girders requires a large amount of working space and equipment.
- A specialized casting yard also had to be constructed for the casting of these girders.
- Approx. 1m wider to conventional segmental box girder. Hence a wider and prestressed pier cap is required.
- Uneconomical for larger spans due to increased weight for erection and larger requirement of working space. Also it becomes very difficult to carry longer spans from casting yard to site.
- At X-over locations the girders are to be connected at slab level hence width of deck slab is increased. Also, changing of bearing at later stage becomes very difficult due to increased weight.

3.8 Construction Sequence

A specialized casting yard as much near to the site as possible is used for the casting of U – Girders. No. of casting beds depends upon the size of the project and the land availability. As the U – Girders are of precast and pretensioned type, therefore a long line method is adopted. No. of units in a single bed are generally restricted to 4 – 6, as the increase in length of units will also increase the prestressing losses. To understand the complete sequence of U – Girder casting and their erection, I visited the casting yard of Greater Noida for which CEC is the contractor. Complete sequence of U – Girder construction can be summarized as below:

1. Placement of reinforcement cage in the prepared formwork.
2. Pretensioning of the strands through the U - Girders.
3. Casting of U - Girders.
4. Removal of formwork.
5. Cutting of strands after initial curing and hardening of concrete.
6. Stacking of casted U - Girders.
7. Loading of U - Girders to treler and unloading at proposed site.
8. Erection of U - Girders.

3.8.1 Preparation of Reinforcement Cage

Reinforcement cage for the U – Girder is prepared adjacent to the casting bed. A temporary staging is used to make both the flanges in their position. Length of bed for cage preparation is generally kept to the same size as that of casting bed.

Figure 3.10 Preparation of Reinforcement Cage

3.8.2 Placement of Reinforcement Cage in the Prepared Formwork

Figure 3.11 Placement of Reinforcement Cage in the Prepared Formwork

Formwork for the outer surface of U – Girders are permanently installed at casting bed. The reinforcement cage is lifted with gantry girders and placed in the prepared formwork. Care should be taken in lifting the cage. To maintain the shape of cage, a truss type arrangement can be used as shown in the fig. above. A no. of hooks at regular intervals (approx. 1m) are connected from top flanges to this truss pipes.

After placing the reinforcement cage, a formwork is installed for the inside surface of U – Girder as shown below:

Figure 3.12 Installation of Formwork for Inside Surface of U-Girder

3.8.3 Pretensioning of the Strands through the U - Girders

After placing the reinforcement cage and formwork, pretensioning strands are inserted from one anchor end. Anchor end is designed to carry the full prestressing force on bed. It is made up of a heavy RCC section and a steel plate with holes is used on outer surface to bear the heavy bearing stresses on anchor end as shown below:

Figure 3.13 A Typical Anchor End

After inserting the HTS (High Tensile Strength) strands through the anchor end, these are anchored depending upon the system of prestressing used. A typical anchorage end with wedges is shown below:

Figure 3.14 Strands Anchored with Wedges at Anchor End

Strands are prestressed at prestressing end with hydraulic systems. All the strands are prestressed simultaneously so as to prevent possibility of plane bending.

Figure 3.15 Prestressing of Strands at Prestressing End

At the prestressing end, all the strands are anchored to a single unit of steel frame which is friction free at its base to move. This frame is connected to hydraulic jacks installed at prestressing end by threaded iron rods.

Figure 3.16 Strands Anchored with Wedges at Prestressing End

Figure 3.17 A Typical detail of Hydraulic Jacks at Prestressing End

3.8.4 Casting of U - Girders

Being pretensioned, therefore casting of U – Girders is done after prestressing is completed. Proper care should be taken during casting of U – Girders. Concrete should be workable enough to reach every parts. High strength concrete is used to achieve the minimum required strength for prestressing in early days. Also, single stage concreting is done to prevent any construction joints.

Figure 3.18 Casting of U – Girders

3.8.5 Removal of Formwork

Formwork is removed after hardening of concrete to facilitate its curing. Formwork on the outer surface is fixed permanently. Although its flanges can tilt towards outer side as shown in fig. below.

Figure 3.19 Removal of Formwork

3.8.6 Cutting of Strands after Initial Curing and Hardening of Concrete

Strands are cut against the hardened concrete after reaching its required compressive strength. The stage of cutting of strands against hardened concrete is called prestress transfer stage.

As per IRC: SP: 71 – 2006, clause 3.2.1 the minimum strength of concrete at transfer shall be such that it satisfies stress check at all stages of construction. Minimum characteristic strength (fck) of concrete shall be M40 and minimum strength at transfer of prestress shall be 0.8 fck or 35MPa, whichever is lesser.

Uncoated Stress Relieved Low Relaxation Seven - Ply Strands in accordance with IS: 14268 – 1995 are used in general.

Figure 3.20 Seven – Ply Strand

3.8.7 Stacking of Casted U - Girders

U – Girders are now removed from the casting bed for Stacking and curing till the time of their use at site for superstructure construction. By doing so, the casing bed is made available for further casting of U – Girders.

Figure 3.21 Stacking of Casted U - Girders

3.8.8 Loading of U - Girders to Treler and Unloading at Proposed Site

Now, as and when the U – Girders are required at site, they can easily be lifted from stacking to the trelers and carried over at site.

Figure 3.22 Loading and Unloading of U - Girders

3.8.9 Erection of U - Girders

U – Girders can easily be lifted by two cranes and placed over pier cap. Their position can further be checked using hydraulic jacks between bearing pedestals.

Figure 3.23 Erection of U - Girders

CHAPTER 4 GENERAL HYPOTHESES

4.1 Introduction

The present report is restricted to analysis and design of a typical span of 27m (c/c of expansion joints) and 16t axle loading. The design basis followed is as mentioned below.

4.2 Design Basis

The design of the U - girder is carried out in accordance with the following documents:

- IRS Concrete Bridge Code: 1997 – Code of Practice for Plain, Reinforced and Prestressed Concrete for General Bridge Construction.
- IRC: 18 – 2000 Design Criteria for Prestressed Concrete Road Bridges.
- IRC: SP: 71 – 2006 Guidelines for Design and Construction of Precast Pretensioned Girders for Bridges.
- IS: 14268 – 2003 Uncoated Stress Relieved Low Relaxation Seven Ply Strand for Prestressed Concrete - Specification.
- IS: 1343 - 2012 Prestressed Concrete – Code of Practice.
- IS: 456 – 2000 Plain and Reinforced Concrete – Code of Practice

The following software's shall be used:

- STAAD.Pro V8i – 2008 Software.
- Microsoft Excel.

4.3 Materials Parameters

Three types of materials has been used in U – Girder: Concrete, Reinforcement and High Tensile Prestressing Strands. Properties of above said materials is taken from the relevant codes of practice.

4.3.1 Concrete Characteristics

Characteristic Concrete Strength:	fck = 55 MPa
Young's Modulus of concrete:	E_c = 35000 MPa
Poisson's Ratio of concrete:	ν = 0.15
Volumetric Weight:	γ = 2.5 t/m^3

4.3.2 Reinforcement

Reinforcement shall be High Yield Strength Deformed Steel Bars conforming to IS: 1786 with the following characteristics:

Grade of Reinforcement:	fy = 500 MPa
Young's Modulus of Reinforcement:	Es = 200000 MPa

4.3.3 Prestressing

Prestressing steel shall be conforming to IS: 14268, class 2 Low Relaxation uncoated stress relieved strands with the following characteristics:

Nominal Area of Strand:	As = 140 mm^2
Minimum Breaking Load:	Pn = 260.7 KN
Nominal Ultimate Stress:	fpu = 1860 MPa
Maximum Jacking Stress:	0.75 fpu = 1395 MPa
Modulus of Elasticity:	Ep = 195000 MPa

4.4 Structure Description

The superstructure consists of Pre-Cast Pre-Tensioned Single U-Girder of 26.95m length, for c/c expansion length of 27m. Bearing to bearing length distance is 25.6m. These dimension details are taken from the typical tender stage drawings published by DMRC for the project say Lucknow Metro, refer drawing nos. LKM-T-SG-TYPI-2051 and LKM-T-SG-TYPI-2060. The purpose to take the same dimensional details was to verify the results of my analysis and design.

The elevation, plan view and cross-sectional view of U – Girder being considered are as shown below.

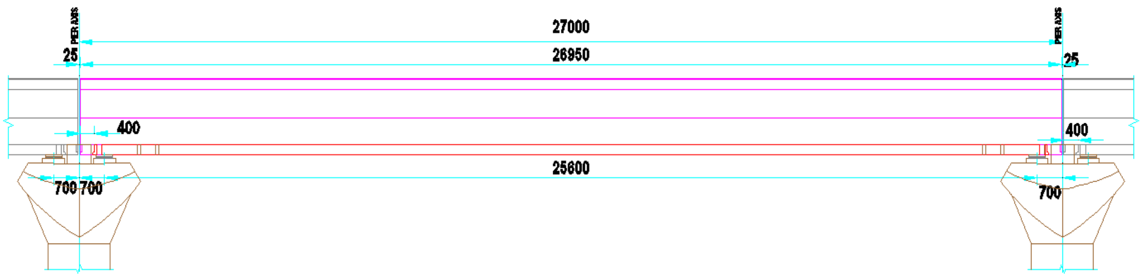


Figure 4.1 Elevation of U – Girder

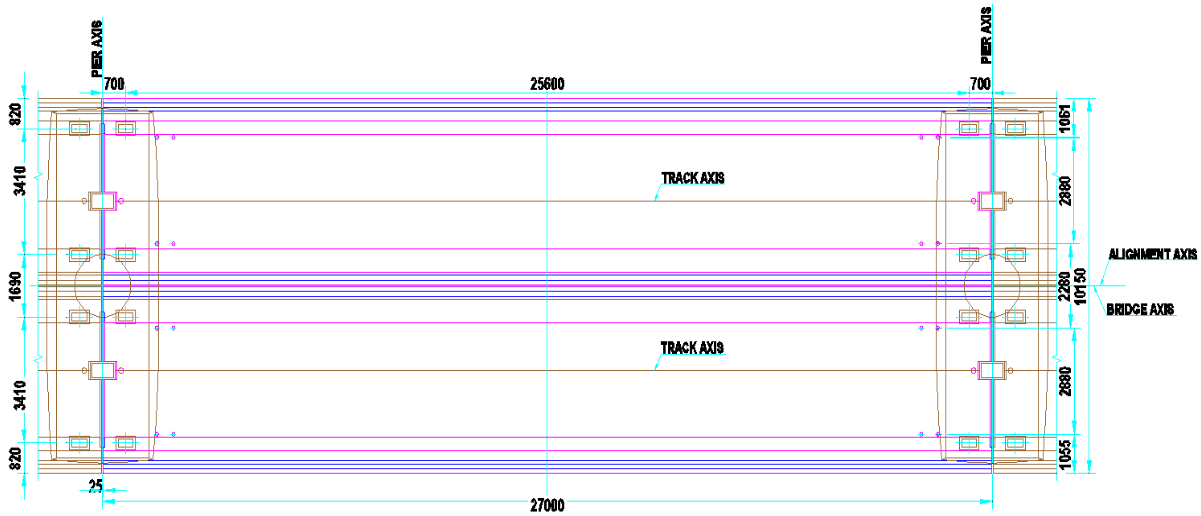


Figure 4.2 Plan View of U – Girder

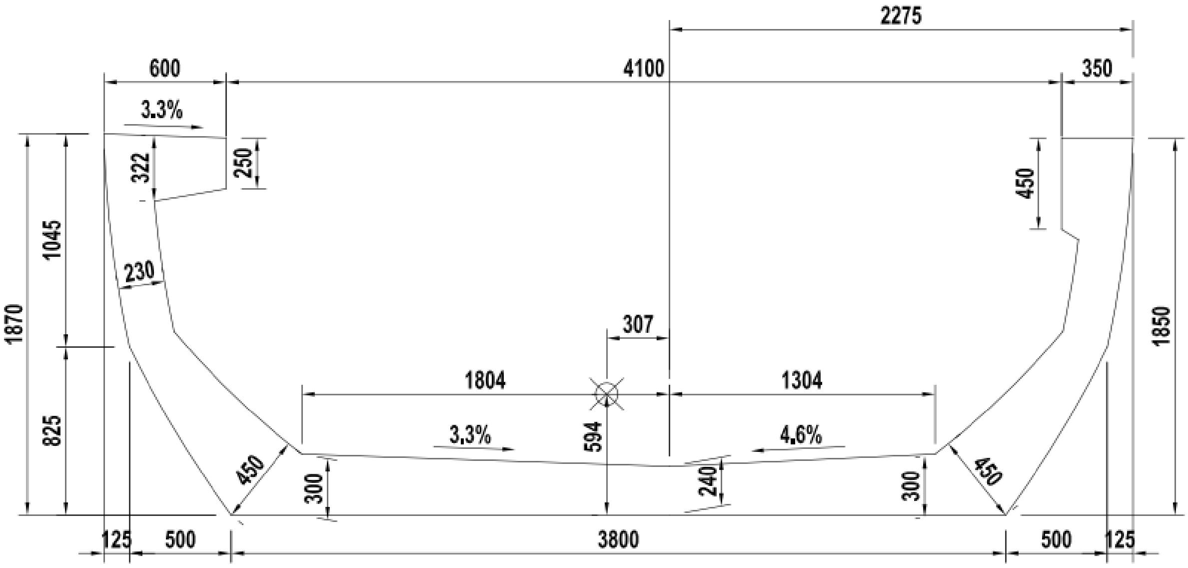


Figure 4.3 Cross-section of U - Girder

4.5 Properties of Cross Section Using Auto Cad

---------------- REGIONS ----------------

Area: 2173501.6

Perimeter: 15875.9

Bounding box: X: -2467.9 -- 2582.1

Y: -593.8 -- 1276.2

Centroid: X: 0.0

Y: 0.0

Moments of inertia: X: 740348288726.4

Y: 6757750989296.6

Product of inertia: XY: -138971378450.3

Radii of gyration: X: 583.6

Y: 1763.3

Principal moments and X-Y directions about centroid:

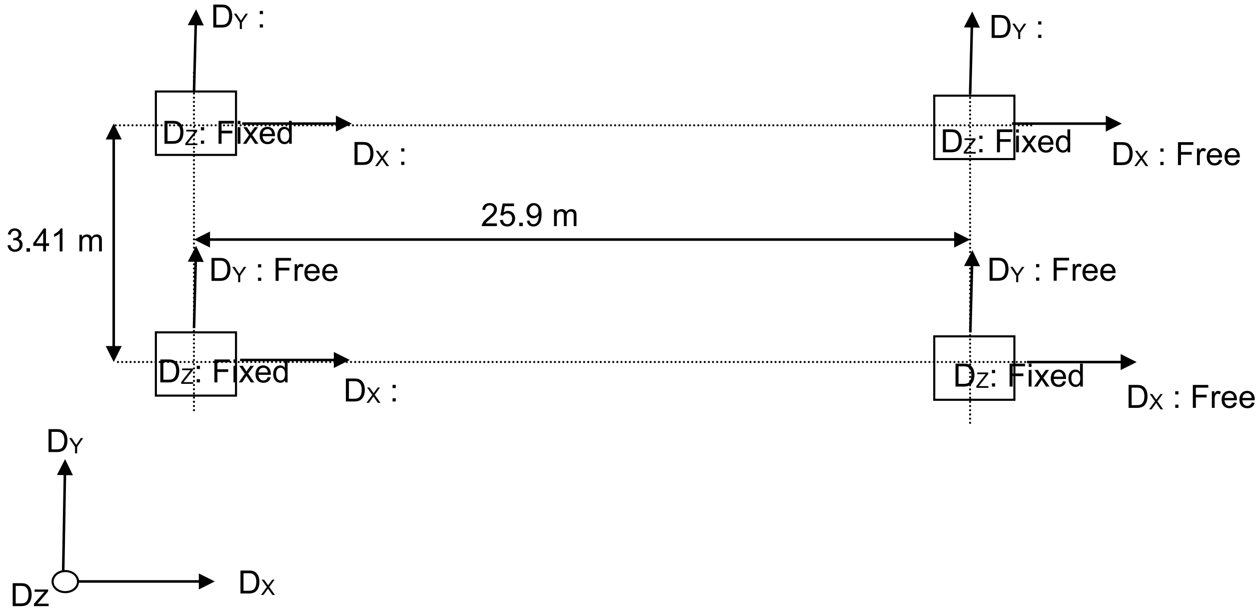
I: 737140464141.3 along [1.0 0.0]

J: 6760958810430.3 along [0.0 1.0]

(Note: All dimensions are in mm).

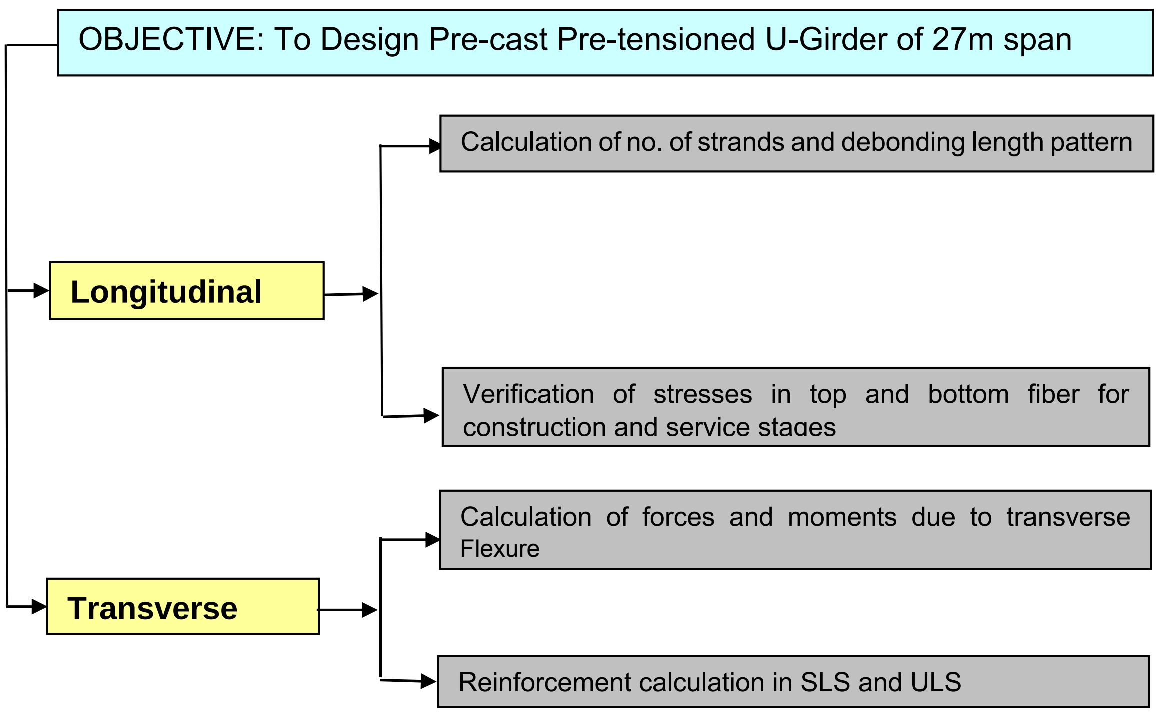
Above properties are calculated from auto cad by using mass property command. It gives accurate values for all sectional properties.

4.6 Support Conditions



4.7 Design Principles

The sketch shown below describes the methodology adopted for the checking of precast pre-tensioned U - Girder of 27m span.



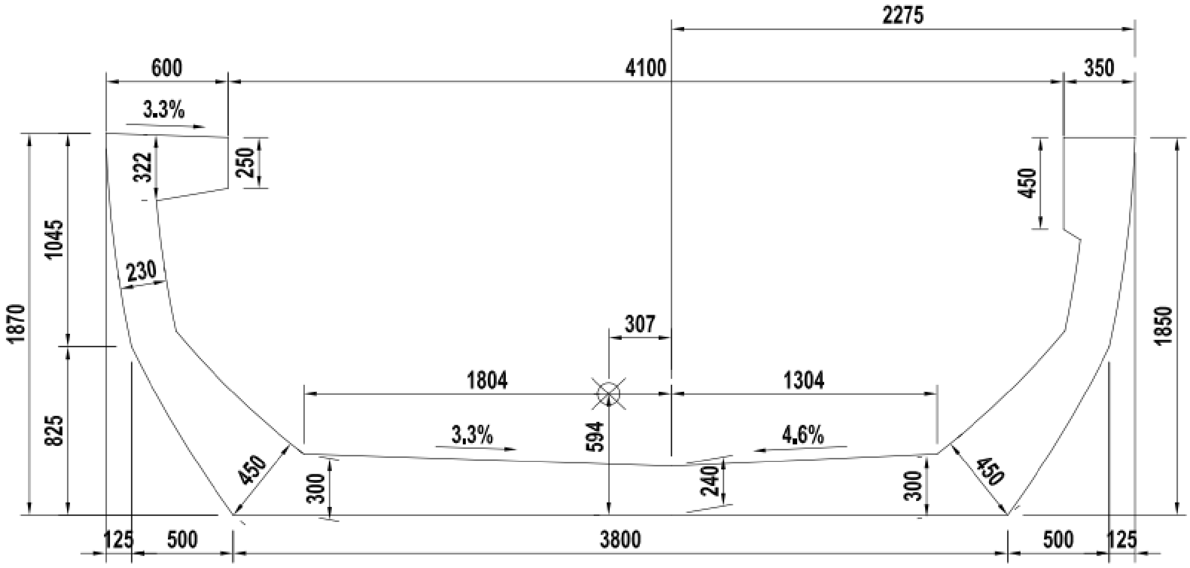
CHAPTER 5 : LONGITUDINAL ANALYSIS

Longitudinal analysis is the analysis of U – Girder along the span length. This is used to determine the amount of prestressing required so as to keep the fiber stresses within the permissible limits.

Followings steps are used for longitudinal analysis:

5.1 Dimensions

c/c of expansion joint Length of the span	=	27.000	m
c/c of bearing Length of the span	=	25.600	m
Projection beyond c/L of bearing	=	0.675	m
Expansion gap	=	0.050	m
Total Width of Superstructure	=	5.050	m



Overall Depth of the structure	=	1.850	m
Average Thickness of deck slab	=	0.270	m
Width of bottom flange of girder	=	3.800	m
Width of web portion of girder	=	0.230	m
Constant depth of bottom flange of girder	=	0.240	m
Variable depth of bottom flange of girder	=	0.060	m
Width of top flange of girder	=	0.950	m
Constant depth of top flange of girder	=	0.250	m
Variable depth of top flange of girder	=	0.072	m
Length of girder having 0.23 m thick web	=	25.600	m
Number of Bearing	=	4	nos.
c/c distance of bearing over support	=	3.410	m

5.2 Design constants

Grade of conc. of U girder		=	M 55	
Grade of steel. of superstructure		=	Fe 500	
Wt. of conc. for self wt. of girder		=	25	kN/m^2
Clear Cover		=	0.040	m
Coefficient of thermal expansion		=	1.17E-05	/ ^oC
Poisson's ratio		=	0.15	
Effective cover for prestressing steel		=	0.105	m

5.3 Pretensioning Detail

Number of Strands per Girder	N1	=	72.0	
Nominal Diameter	D	=	15.2	mm
Nominal Area	A	=	140	mm2
Nominal Mass	Pu	=	1.1	Kg/m
Yield Strength	Fy	=	1670	MPa
Tensile Strength	Fu	=	1860	MPa
Minimum Breaking Load	Pn	=	260.7	KN
Young's Modulus of Elasticity	Eps	=	195	Gpa
Jacking Force at Transfer (% of Breaking Load)	Pj	=	75	%
Casting of Girder		=	0	days
Release of Prestressing Force after		=	3	days
Placement of girder for stacking		=	10	days
Casting of track plinth		=	28	days
Release of shuttering after		=	42	days
Fixing of rails		=	56	days
Traffic Allowance after		=	56	days
Min. Comp. strength of girder at prestress transfer		=	35	N/mm^2
Min. Comp. strength of girder during lifting		=	35	N/mm^2
Elastic Modulus of U girder at prestress transfer		=	29580	N/mm^2
Elastic Modulus of U girder during lifting		=	29580	N/mm^2
Modular ratio of prestressing steel and concrete at transfer		=	6.59	
Relaxation loss at 1000 hrs at 70% UTS (as % of initial stress), Re1		=	2.5	
Relaxation loss at 1000 hrs at 50% UTS (as % of initial stress), Re2		=	0	
Temporary Stage				
Permissible compressive stress in temporary condition (0.5 fcj)		=	17500	kN/m^2
Permissible tensile stress in temporary condition (1/10*0.5 fcj)		=	-1750	kN/m^2
Service Stage				
Permissible compressive stress in service condition (0.33fcj)		=	18150	kN/m^2
Permissible tensile stress in service condition at girder top (0.36 sqrt(fck))		=	-2670	kN/m^2

(As per clause 3.2.2 of IRC:SP:71-2006)

5.4 Section Properties

5.4.1 At Mid Span

Using Auto cad

Area	ΣA	=	2.173	m^2
Distance of cg from bottom fibre	$Y_{cg} = \Sigma(A.y) / \Sigma A$	=	0.594	m
Moment of inertia of U girder		=	0.740	m^4
$Iz = \Sigma(Io + A.y^2) - \Sigma A \cdot Y_{cg}$				
Moment of Area of the section above centroid $\Sigma A.y$		=	1.290	m^3

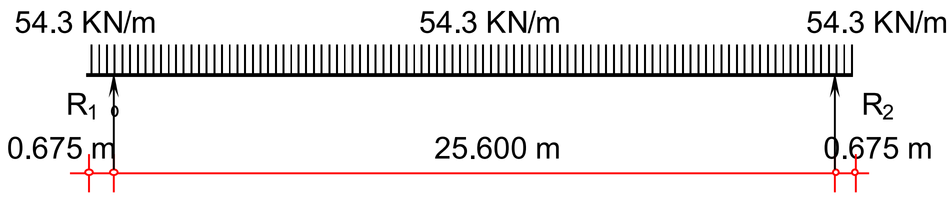
5.4.2 At End

Area	ΣA	=	2.173	m^2
Distance of cg from bottom fibre	$Y_{cg} = \Sigma(A.y) / \Sigma A$	=	0.594	m
Moment of inertia of U girder		=	0.740	m^4
$Iz = \Sigma(Io + A.y^2) - \Sigma A \cdot Y_{cg}$				
Moment of Area of the section above centroid $\Sigma A.y$		=	1.290	m^3

5.5 Bending Moment & Shear Force at different Stages of Loading

Total length of the precast unit		=	26.950	m
Projection of Girder beyond Support		=	0.675	m
C/C spacing of Bearing		=	25.600	m
Area of Girder at the Span		=	2.173	m^2
Area of Girder at the Support		=	2.173	m^2
Density of Concrete Girder		=	25	KN/m^3
Self Wt. of girder at center	= 2.173 * 25	=	54.3	KN/m

5.5.1 Stage-1 Loading: Self Weight of U - Girder



Support Reaction R_1 = 732.0 KN

As the U – Girder is having same cross-sectional area throughout its length, its bending moment is simply $wl^2/8$ at center. Values at other locations can be determined from equations of equilibrium. I have also cross checked the values from Staad output to confirm my sectional properties.

Item	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
From brg c/L	0.0	1.5	2.6	5.1	7.7	10.2	12.80
Support load	732.0	732.0	732.0	732.0	732.0	732.0	732.0
UDL	36.7	118.2	175.7	314.8	453.9	593.0	732.0
UDL C.G	0.3	1.1	1.6	2.9	4.2	5.5	6.7
Sup. Mom.	0.0	1098.0	1874.0	3748.0	5622.0	7496.0	9370.0
UDL Moment	12.4	128.5	284.3	912.2	1896.1	3236.1	4932.0
BM (KNm)	-12.4	969.5	1589.7	2835.8	3725.9	4259.9	4437.9
SF (KN)	695.4	613.9	556.3	417.2	278.1	139.1	0.0

These results can be verified from Staad as below:

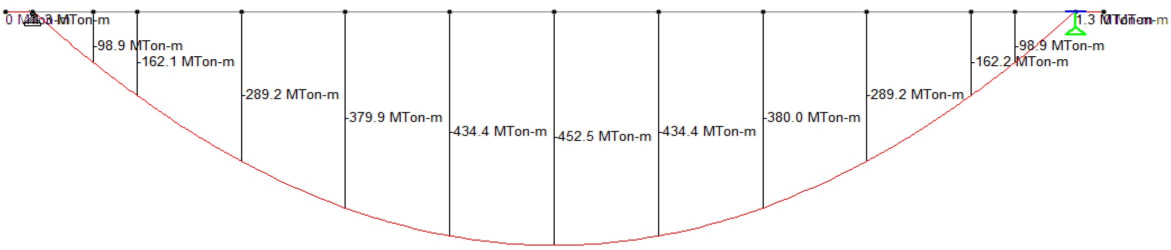


Figure 5.1 BMD due to Stage-1 Loading i.e. Self-Weight

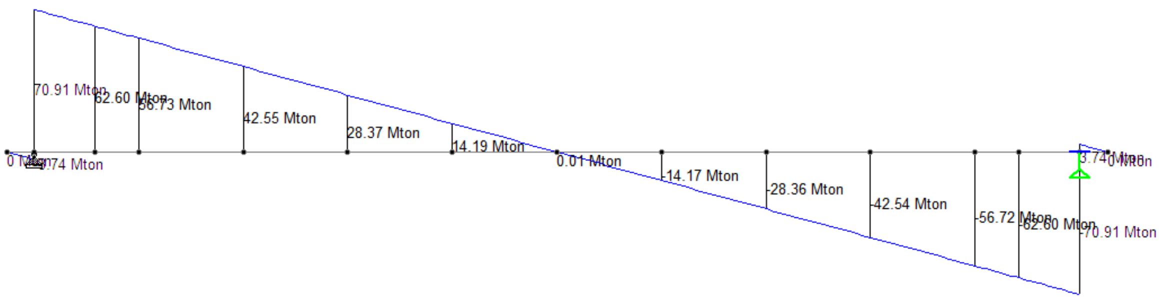


Figure 5.2 SFD due to Stage-1 Loading i.e. Self-Weight

5.5.2 Stage-2 Loading: SIDL (Track Plinth)

This is the stage when U – Girder is placed over bearings and track plinth is casted. As per DBR (Design Basis Report) of DMRC, weight of track plinth is 3.1 t/m for two tracks i.e. 1.55 t/m for each track. BMD and SFD for this loading at various sections are as under:

Item	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
From brg c/L	0.0	1.5	2.6	5.1	7.7	10.2	12.8
BM (KNm)	-3.5	276.6	453.6	809.1	1063.1	1215.4	1266.2
SF (KN)	198.4	175.2	158.7	119.0	79.4	39.7	0.0

5.5.3 Stage-3 Loading: SIDL (Cables + Rails + Hand Rail etc.)

This is the final stage of construction when all the miscellaneous work has been carried out. It includes fixing of rails over plinth, cables and cable trays, hand rails over webs, OHE masts and other signaling works etc. As per DBR (Design Basis Report) of DMRC, total weight of SIDL is 4.5 t/m for two tracks i.e. 2.25 t/m for each track. Out of which, 1.55 t/m is due to track plinth being considered at stage 2. Therefore, remaining load is 0.7 t/m for stage 3. BMD and SFD for this loading at various sections are as under:

Item	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
From brg c/L	0.0	1.5	2.6	5.1	7.7	10.2	12.8
BM (KNm)	-1.6	124.9	204.8	365.4	480.1	548.9	571.8
SF (KN)	89.6	79.1	71.7	53.8	35.8	17.9	0.0

Total Bending moment and shear forces due to SIDL (including stage 2 and 3) can be verified from Staad as below:

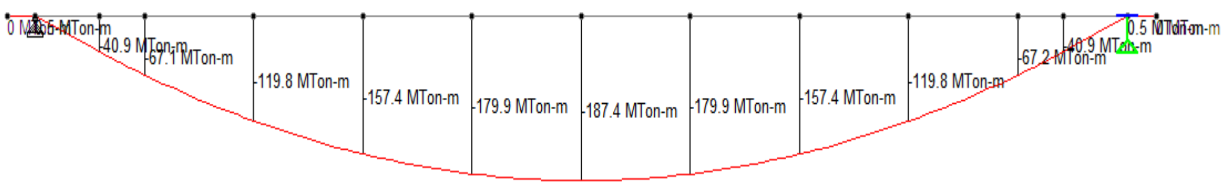


Figure 5.3 BMD due to Stage-2 & 3 Loading i.e. SIDL

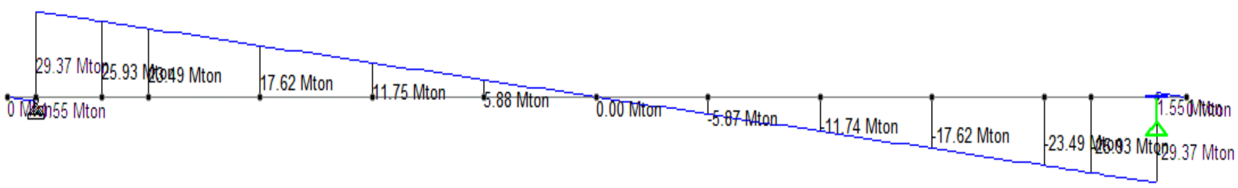


Figure 5.4 SFD due to Stage-2 & 3 Loading i.e. SIDL

5.5.4 Stage-4 Loading: Live Load

This is the service stage when the U – Girder is in service.

5.5.4.1 Impact Factor

As per IRC: 6 – 2014, clause 208.2 impact factor for RCC bridge can be determined using:

Impact Factor, I.F. = 1 + 4.5 / (6 + L)

Where L = Span length in m.

This implies, I.F. = 1 + 4.5 / (6 + 25.6) = 1.14

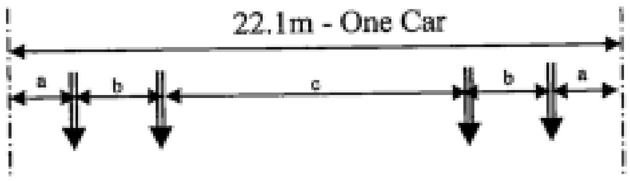
But, as per DMRC's DBR i.e. volume 4 of any tender document say NC01, clause no. 2.9 page no. 18, impact factor for longitudinal analysis shall be 1.2 while for transverse analysis the same shall be 1.67.

Adopting an impact factor of 1.2.

This implies that the train axle load = 16 x 1.2 = 19.2 t.

5.5.4.2 Train Load Configuration

The train live load will be "Modern Rolling Stock" type with the two following axle configuration:



All axle loads = 16 tons
Maximum number of successive cars: 6
Maximum service speed of train is: 80 kmph

Configuration 1:
a = 2.25m
b = 2.50m
c = 12.60m ➔ (2a+2b+c=22.1m)
Configuration 2:
a = 2.605m
b = 2.290m
c = 12.310m ➔ (2a+2b+c=22.1m)

Figure 5.5 16t Rolling Stock Configuration

5.5.4.3 Bending Moment and Shear Force due to Live Load

Item	Support	Debonded	0.10L	0.20L	0.30L	0.40L	0.50L
Frm brg c/L	0.00	1.50	2.56	5.12	7.68	10.24	12.80
BM (KNm)	-13	88	142	241	313	354	357
SF (KN)	66	59	55	47	39	32	24

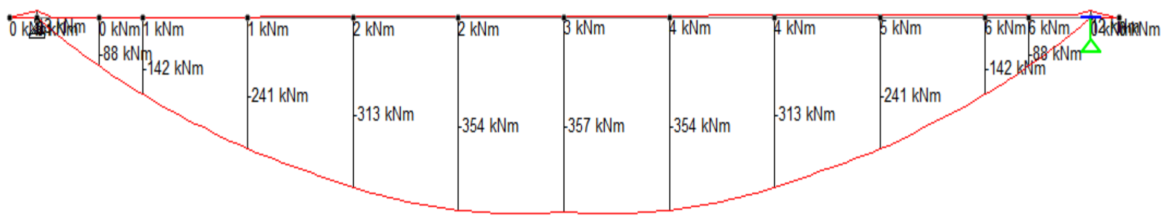


Figure 5.6 BMD due to Stage-4 Loading i.e. LL

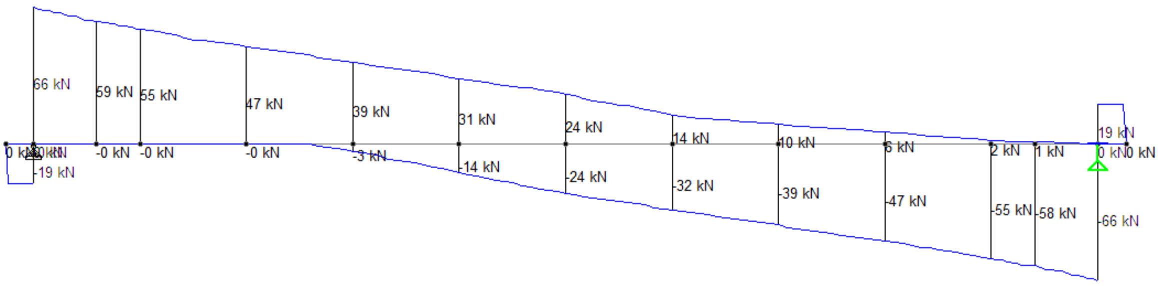


Figure 5.7 BMD due to Stage-4 Loading i.e. LL

5.6 Bending Moment & Shear Force Summary

Stage-1 Loading : Self weight of girder

Item	Support	Debonded	0.1	0.2	0.3	0.4	0.5
Dist. frm brg cL(m)	0.00	1.50	2.56	5.12	7.68	10.24	12.80
BM (KNm)	-12	970	1590	2836	3726	4260	4438
SF (KN)	695	614	556	417	278	139	0

Stage-2 Loading : SIDL (Track Plinth)

Item	Support	Debonded	0.1	0.2	0.3	0.4	0.5
Dist. frm brg cL(m)	0.00	1.50	2.56	5.12	7.68	10.24	12.80
BM (KNm)	-4	277	454	809	1063	1215	1266
SF (KN)	198	175	159	119	79	40	0

Stage-3 Loading : SIDL (cables + rails + hand rail etc)

Item	Support	Debonded	0.1	0.2	0.3	0.4	0.5
Dist. frm brg cL(m)	0.00	1.50	2.56	5.12	7.68	10.24	12.80
BM (KNm)	-2	125	205	365	480	549	572
SF (KN)	90	79	72	54	36	18	0

Stage-4 Loading (Service Stage)

Item	Support	Debonded	0.1	0.2	0.3	0.4	0.5
Dist. frm brg cL(m)	0.00	1.50	2.56	5.12	7.68	10.24	12.80
BM (KNm)	-13	88	142	241	313	354	357
SF (KN)	66	59	55	47	39	32	24

5.6.1 Load Combination

According to IRC: 18 – 2000 clause 12, a prestressed concrete structure and its constituents members shall be checked for failure conditions at an ultimate load of

1.25 G + 2.0 SG + 2.5 Q. Where G, SG and Q denotes permanent dead load, superimposed dead load and live load including impact respectively.

Thus, the load combinations for ultimate bending moment and ultimate shear forces are as under:

BM_{ult} = 1.25 DL + 2.0 SIDL + 2.5 LL

SF_{ult} = 1.25 DL + 2.0 SIDL + 2.5 LL

Load Combination

Item	Support	Debonded	0.1	0.2	0.3	0.4	0.5
Dist. from brg c/L	0.00	1.50	2.56	5.12	7.68	10.24	12.80
BM_{ult} (Precast section) (KNm)	-15	1212	1987	3545	4657	5325	5547
BM_{ult} (service) (KNm)	-58	2235	3659	6496	8526	9739	10116
SF_{ult} (Precast section) (KN)	869	767	695	522	348	174	0
SF_{ult} (service) (KN)	1610	1423	1294	985	676	369	60

5.7 Design of U – Girder

Top and Bottom Fiber stresses of U – Girder can be checked using the following steps:

5.7.1 Details of Girder Property

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Area of the section, A	m^2	2.173	2.173	2.173	2.173	2.173	2.173	2.173
Depth of the section, d	m	1.850	1.850	1.850	1.850	1.850	1.850	1.850
CG of section from bottom, Y_b	m	0.594	0.594	0.594	0.594	0.594	0.594	0.594
Inertia of section, I_{x-x}	m^4	0.740	0.740	0.740	0.740	0.740	0.740	0.740
Top Section Modulus, Z_t	m^3	0.589	0.589	0.589	0.589	0.589	0.589	0.589
Bottom Section Modulus, Z_b	m^3	1.246	1.246	1.246	1.246	1.246	1.246	1.246

5.7.2 Self-Weight Moments

Moment	KNm	-12.4	969.5	1589.7	2835.8	3725.9	4259.9	4437.9
Stress at Top Fibre, $s_t = M/Z_t$	KN/m^2	-21.0	1645.9	2698.7	4814.0	6324.9	7231.5	7533.7
Stress at Bottom Fibre, $s_b = M/Z_b$	KN/m^2	9.9	-778.0	-1275.7	-2275.6	-2989.8	-3418.3	-3561.1

5.7.3 Prestressing Details

These are kept of the same amount as provided in tender document of Lucknow Metro (refer drawing no. LKM-T-SG-TYPI-2062) so as to be on the same input parameters. Prestressing cables are provided in two layers in deck slab as shown below.

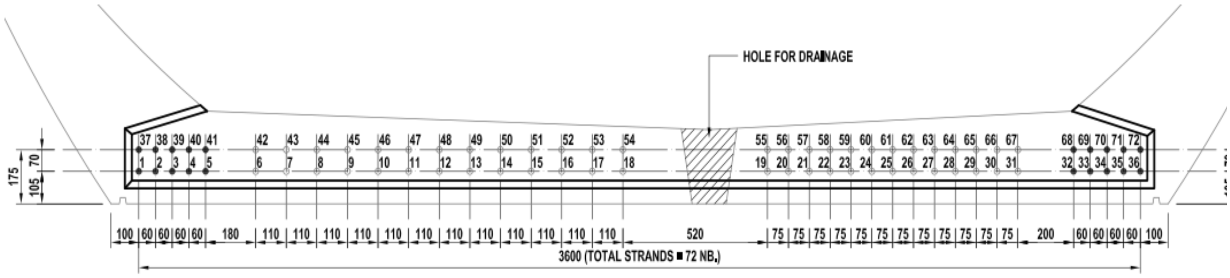


Figure 5.8 Prestressing Detail – Typical Cross-section

Item	Unit	Support	Debonded	0.10L	0.20L	0.30L	0.40L	0.50L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
No. of Strands in Layer-1	(Nos.)	10	10	36	36	36	36	36
No. of Strands in Layer-2	(Nos.)	10	10	36	36	36	36	36
Total Number of Strands	(Nos.)	20	20	72	72	72	72	72
No. of Debonded Strands in Layer-1	(Nos.)	0	26	0	0	0	0	0
No. of Debonded Strands in Layer-2	(Nos.)	0	26	0	0	0	0	0
% of Total Curtailment	%	0	72	0	0	0	0	0
No. of Strands debonded	(Nos.)	0	52	0	0	0	0	0
Debonded Length	(mm)	12600	11300	0	0	0	0	0
Eccen. of strands from bottom in Layer-1	(m)	0.105	0.105	0.105	0.105	0.105	0.105	0.105
Eccen. of strands from bottom in Layer-2	(m)	0.175	0.175	0.175	0.175	0.175	0.175	0.175
Area of each strand	m^2	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014
CG of Strands from Bottom	(m)	0.140	0.140	0.140	0.140	0.140	0.140	0.140
Prestress Force/strand	KN	196	196	196	196	196	196	196
Total Prestress Force (Provided)	KN	3910.5	3910.5	14077.8	14077.8	14077.8	14077.8	14077.8

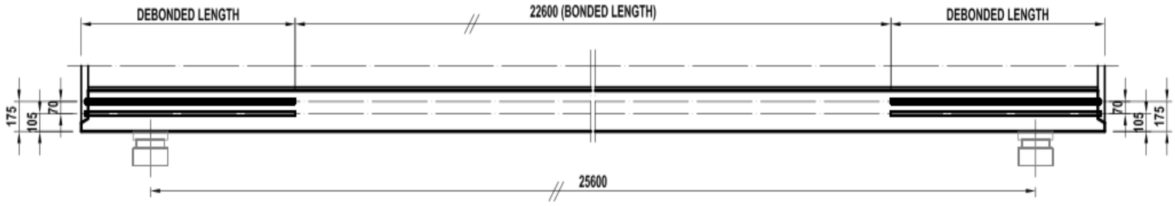


Figure 5.9 Prestressing Detail – Longitudinal Section

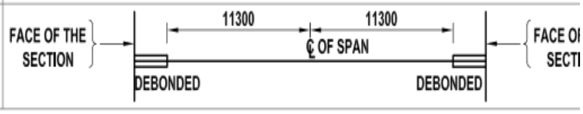
1,2,3,4,5,32,33,34,35,36, 37,38, 39,40,41,68,69,70,71,72	20	FULL LENGTH BONDED	
6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25, 26,27,28,29,30,31,42,43,44,45,46,47,48,49,50,51,52, 53,54,55,56,57,58,59,60,61,62,63,64,65,66,67	52	22600	

Figure 5.10 Prestressing Detail – Bonding / Debonding Schedule

5.7.4 Relaxation loss (0 - 3 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Initial Stress as % of UTS (fp)	fp	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Relaxation loss for low relaxation steel at 1000 hrs. (Ref. Table 4.A, IRC:18 - 2000)	%	3.500	3.500	3.500	3.500	3.500	3.500	3.500
Time after prestressing	hr.	72						
Relaxation loss as % of loss at 1000 hrs. (Ref. Table 4.B, IRC:18-2000)	%	48.000						
Relaxation loss at support for 0 to 3 days	=	1 x 3.5 / 100 x 48 / 100 x 3910.5						
	KN	65.7	65.7	236.5	236.5	236.5	236.5	236.5
Effective Prestress Force at transfer	KN	3845	3845	13841	13841	13841	13841	13841
% of Prestressing Force at transfer	%	73.740	73.740	73.740	73.740	73.740	73.740	73.740
Prestressing Factor (Top) ($1/A-e/Z_t$)	m^{-2}	-0.310	-0.310	-0.310	-0.310	-0.310	-0.310	-0.310
Prestressing Factor (Bottom) ($1/A+e/Z_b$)	m^{-2}	0.824	0.824	0.824	0.824	0.824	0.824	0.824
Stress at Top Fibre due to prestress	KN/m^2	-1193	-1193	-4293	-4293	-4293	-4293	-4293
Stress at Bottom Fibre due to prestress	KN/m^2	3169	3169	11410	11410	11410	11410	11410
Cumulative Stress at Top Fibre, σ_t	KN/m^2	-1213.5	453.4	-1594.4	520.9	2031.9	2938.4	3240.6
Cumulative Stress at Bottom Fibre, σ_b	KN/m^2	3179.3	2391.4	10134.2	9134.3	8420.1	7991.6	7848.8
Stress at CG of Tendon	KN/m^2	2846.9	2244.8	9246.7	8482.5	7936.7	7609.2	7500.0

In the case of pre tensioned concrete, relaxation losses start as soon as the pretensioning is carried out, whereas, the effect of the same on the concrete begins only after the prestressing force is transferred to the concrete. In this regard, relaxation losses shall be calculated as per Table 4A and 4B of IRC: 18 for assessment of actually available prestressing force at transfer.

Table 4A

Relaxation loss at 1000 hours at 20°C ± 2°C (as % of initial stress)

Initial stress	Relaxation loss for Normal relaxation steel (%)	Relaxation loss for low relaxation steel (%)
0.5 fp	0	0
0.6 fp	2.5	1.25
0.7 fp	5.0	2.5
0.8 fp	9.0	4.5

Notes: (i) For intermediate values linear interpolation may be done
(ii) fp = Minimum Ultimate Tensile Stress (UTS) of steel

IRC : 18-2000

Table 4B

Relation between relaxation losses and time upto 1000 hours.

Time in Hours	1	5	20	100	200	500	1000
Relaxation loss as % of loss at 1000 hrs	15	25	35	55	65	85	100

Figure 5.11 Relaxation Loss of Prestressing Steel as per IRC : 18 - 2000

5.7.5 Elastic Shortening Loss during Detensioning

According to IRC: SP: 71 – 2006 clause 3.5.1, the loss of stress (f_{PES} in MPa) in the prestressing steel in pre-tensioned girder shall be calculated as:

$$f_{pES} = \frac{E_p}{E_{ci}} f_{cgp}$$

Where,

f_{cgp} = sum of concrete stresses at the centre of gravity of prestressing tendons due to the prestressing force at transfer and the self-weight of the member at the sections of maximum moment (MPa)

Ep = modulus of elasticity of prestressing steel (MPa)

Eci = modulus of elasticity of concrete at transfer (MPa)

The above method is different from that given in clause 11.1 of IRC: 18 - 2000 as unlike post-tensioning, all the strands are stressed at the same time and the forces transferred to the concrete simultaneously.

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Loss in Force	KN	52.5	41.4	614.4	563.6	527.4	505.6	498.4
Stress for Elastic Shortening Loss								
Top	KN/m^2	16.3	12.9	190.6	174.8	163.6	156.8	154.6
Bottom	KN/m^2	-43.3	-34.2	-506.5	-464.6	-434.7	-416.8	-410.8
Cumulative Stress after E. S. loss								
Cumulative Stress at Top Fibre, s_t	KN/m^2	-1197	466	-1404	696	2195	3095	3395
Cumulative Stress at Bottom Fibre, s_b	KN/m^2	3136	2357	9628	8670	7985	7575	7438
Check for loss due to elastic shortening	=	2846.912 x 6.592 x 0.00014 x 20						
Iteration value	KN	52.5	41.4	614.4	563.6	527.4	505.6	498.4
Difference	KN	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.7.6 Losses in prestress, 3 - 28 days

5.7.6.1 Relaxation loss (3 - 28 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Prestressing force up to 3 days.	KN	3792.3	3803.4	13226.9	13277.7	13313.9	13335.7	13342.9
Initial Stress as % of UTS (f_p)	f_p	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Relaxation loss for low relaxation steel at 1000 hrs.	%	3.500	3.500	3.500	3.500	3.500	3.500	3.500
Time after prestressing	hr.	672						
Relaxation loss as % of loss at 1000 hrs.	%	90.160						
Relaxation loss for 3 to 28 days	=	1 x 3.5 / 100 x (90.16 - 48) / 100 x 3910.5						
	KN	57.7	57.7	207.7	207.7	207.7	207.7	207.7

5.7.6.2 Shrinkage loss (3 - 28 days)

Residual Shrinkage Strain at	3 days	0.00043						
Residual Shrinkage Strain at	28days	0.00019						
Shrinkage loss for 3 to 28 days	KN	= (0.00043 - 0.00019) * 20 * 140* 195000 * 1/1000						
	KN	131.0	131.0	471.7	471.7	471.7	471.7	471.7

5.7.6.3 Creep loss (3 - 28 days)

Creep Strain / 10 Mpa at	3 days	0.00068						
Creep Strain / 10 Mpa at	28days	0.00040						
Creep Loss	KN	41.6	32.6	460.8	421.6	393.6	376.8	371.2
Total Loss (Relaxation + Shrinkage + Creep)	KN	230.4	221.3	1140.2	1101.0	1073.0	1056.2	1050.6
Stress after (R + S + C) loss								
Top	KN/m^2	71.5	68.7	353.7	341.5	332.8	327.6	325.9
Bottom	KN/m^2	-189.9	-182.5	-939.9	-907.6	-884.6	-870.7	-866.1

5.7.6.4 Cumulative Stress after R + S + C loss (3 – 28 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Cumulative Stress at Top Fibre, s_t	KN/m^2	-1126	535	-1050	1037	2528	3423	3721
Cumulative Stress at Bottom Fibre, s_b	KN/m^2	2946	2175	8688	7762	7101	6704	6572
Average Stress at Top Fibre, s_t	KN/m^2	-1161	501	-1227	867	2362	3259	3558
Average Stress at Bottom Fibre, s_b	KN/m^2	3041	2266	9158	8216	7543	7139	7005
Stress at CG of Tendon	KN/m^2	2723.0	2132.4	8371.9	7659.7	7151.0	6845.8	6744.1
Check for loss due to creep of concrete	=	1 x (0.0007 - 0.0004) / 10 x 2723 / 1000 x 20 x 0.00014 x 195 x 1000000						
Iteration value	KN	41.6	32.6	460.8	421.6	393.6	376.8	371.2
Difference	KN	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.7.7 Track Plinth Moments

Moment	KNm	-3.5	276.6	453.6	809.1	1063.1	1215.4	1266.2
Stress at Top Fibre, s_t	KN/m^2	-6.0	469.6	770.0	1373.5	1804.6	2063.3	2149.5
Stress at Bottom Fibre, s_b	KN/m^2	3	-222	-364	-649	-853	-975	-1016
Cumulative Stress after R + S + C loss								
Cumulative Stress at Top Fibre, s_t	KN/m^2	-1132	1004	-280	2411	4333	5486	5871
Cumulative Stress at Bottom Fibre, s_b	KN/m^2	2949	1953	8324	7113	6248	5729	5556

5.7.8 Losses in prestress, 28 - 42 days

5.7.8.1 Relaxation loss (28 - 42 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Prestressing force at 28 days.	KN	3561.9	3582.0	12086.6	12176.6	12240.9	12279.4	12292.3
Initial Stress as % of UTS (f_p)	f_p	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Relaxation loss for low relaxation steel at 1000 hrs.	%	3.500	3.500	3.500	3.500	3.500	3.500	3.500
Time after prestressing	hr.	1008						
Relaxation loss as % of loss at 1000 hrs.	%	100.240						
Relaxation loss for 28 to 42 days	KN	(100.24 - 90.16) % x 1 x 3.5 % x 3910.5						
	KN	13.8	13.8	49.7	49.7	49.7	49.7	49.7

5.7.8.2 Shrinkage loss (28 - 42 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Residual Shrinkage Strain at	28 days	0.00019						
Residual Shrinkage Strain at	42 days	0.00018						
Shrinkage loss for 28 to 42 days	KN	= (0.00019 - 0.000181) * 20 * 140* 195000 * 1/1000						
	KN	4.9	4.9	17.8	17.8	17.8	17.8	17.8

5.7.8.3 Creep loss (28 - 42 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Creep Strain / 10 Mpa at	28 days	0.00040						
Creep Strain / 10 Mpa at	42 days	0.00039						
Creep Loss	KN	1.3	0.9	13.6	11.9	10.8	10.1	9.9
Total Loss (Relaxation + Shrinkage + Creep)	KN	20.0	19.7	81.0	79.4	78.2	77.5	77.3
Stress after (R + S + C) loss								
Top	KN/m^2	6.2	6.1	25.1	24.6	24.3	24.0	24.0
Bottom	KN/m^2	-16.5	-16.2	-66.8	-65.4	-64.5	-63.9	-63.7

5.7.8.4 Cumulative Stress after R + S + C loss (28 - 42 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Cumulative Stress at Top Fibre, s_t	KN/m^2	-1126	1011	-255	2435	4357	5510	5895
Cumulative Stress at Bottom Fibre, s_b	KN/m^2	2932	1937	8257	7047	6183	5665	5492
Average Stress at Top Fibre, s_t	KN/m^2	-1129	1008	-268	2423	4345	5498	5883
Average Stress at Bottom Fibre, s_b	KN/m^2	2941	1945	8290	7080	6216	5697	5524
Stress at CG of Tendon	KN/m^2	2632.8	1873.8	7642.8	6727.7	6074.0	5681.8	5551.1
Check for loss due to creep of concrete	=	1 x (0.0004 - 0.0004) / 10 x 2632.8 / 1000 x 20 x 0.00014 x 195 x 1000000						
Iteration value	=	1.3	0.9	13.6	11.9	10.8	10.1	9.9
Difference	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.7.9 Losses in prestress, 42 - 56 days

5.7.9.1 Relaxation loss (42 – 56 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Prestressing force up to 42 days.	KN	3541.9	3562.4	12005.6	12097.2	12162.7	12201.9	12215.0
Initial Stress as % of UTS (f_p)	f_p	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Relaxation loss for low relaxation steel at 1000 hrs.	%	3.500	3.500	3.500	3.500	3.500	3.500	3.500
Time after prestressing	hr.	1272						
Relaxation loss as % of loss at 1000 hrs.	%	0.000						
Relaxation loss for 42 to 56 days	KN	(0 - 100.24) % x 1 x 3.5 % x 3910.5						
	KN	-137.2	-137.2	-493.9	-493.9	-493.9	-493.9	-493.9

5.7.9.2 Shrinkage loss (42 – 56 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Residual Shrinkage Strain at	42 days	0.00018						
Residual Shrinkage Strain at	56 days	0.00017						
Factor For Time dependent loss		1.0						
Shrinkage loss for 42 to 56 days	KN	= (0.000181 - 0.000172) * 20 * 140* 195000 * 1/1000						
	KN	4.9	4.9	17.8	17.8	17.8	17.8	17.8

5.7.9.3 Creep loss (42 – 56 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Creep Strain / 10 Mpa at	42 days	0.00039						
Creep Strain / 10 Mpa at	56 days	0.00038						
Creep Loss	KN	1.3	0.9	13.5	11.9	10.7	10.0	9.8
Total Loss (Relaxation + Shrinkage + Creep)	KN	6.0	5.7	30.6	29.0	27.8	27.1	26.9
Stress after (R + S + C) loss								
Stress at Girder Top, s_{tg}	KN/m^2	1.9	1.8	9.5	9.0	8.6	8.4	8.3
Stress at Girder Bottom, s_{bg}	KN/m^2	-5.0	-4.7	-25.2	-23.9	-22.9	-22.4	-22.2

5.7.9.4 Cumulative Stress after R + S + C loss (42 – 56 days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Stress at Deck Top, s_{td}	KN/m^2	2	2	9	9	9	8	8
Stress at Girder Top, s_{tg}	KN/m^2	-1124	1012	-246	2444	4366	5519	5903
Stress at Girder Bottom, s_{bg}	KN/m^2	2927	1932	8232	7024	6160	5643	5470
Average Stress at Girder Top, s_{tg}	KN/m^2	-1125	1011	-250	2440	4361	5514	5899
Average Stress at Girder Bottom, s_{bg}	KN/m^2	2930	1934	8244	7035	6172	5654	5481
Stress at CG of Tendon	KN/m^2	2623.1	1864.4	7601.6	6687.7	6034.9	5643.2	5512.6
Iteration value	=	1.3	0.9	13.5	11.9	10.7	10.0	9.8
Difference		0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.7.10 Details of Girder Property-28 days old

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Area of the section, A	m^2	2.173	2.173	2.173	2.173	2.173	2.173	2.173
Depth of the section, d	m	1.850	1.850	1.850	1.850	1.850	1.850	1.850
CG of section from bottom, Y_b	m	0.594	0.594	0.594	0.594	0.594	0.594	0.594
Inertia of section, $I_{x\text{-}x}$	m^4	0.740	0.740	0.740	0.740	0.740	0.740	0.740
Top Section Modulus, Z_t	m^3	0.589	0.589	0.589	0.589	0.589	0.589	0.589
Bottom Section Modulus, Z_b	m^3	1.246	1.246	1.246	1.246	1.246	1.246	1.246
CG of Tendons from Bottom Y_{ord}	m	0.140	0.140	0.140	0.140	0.140	0.140	0.140
Prestressing Factor (Top) ($1/A-e/Z_t$)	m^{-2}	-0.310	-0.310	-0.310	-0.310	-0.310	-0.310	-0.310
Prestressing Factor (Bottom) ($1/A+e/Z_b$)	m^{-2}	0.824	0.824	0.824	0.824	0.824	0.824	0.824

5.7.11 SIDL Moments

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Moments	KNm	-1.6	124.9	204.8	365.4	480.1	548.9	571.8
Stress at Girder Top, s_{tg}	KN/m^2	-2.7	212.1	347.7	620.3	815.0	931.8	970.7
Stress at Girder Bottom, s_{bg}	KN/m^2	1.3	-100.2	-164.4	-293.2	-385.2	-440.5	-458.9

5.7.11.1 Cumulative Stresses after SIDL

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Stress at Girder Top, s_{tg}	KN/m^2	-1126	1224	102	3065	5181	6450	6874
Stress at Girder Bottom, s_{bg}	KN/m^2	2929	1832	8067	6730	5775	5202	5011

5.7.12 Live Load Moments

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Moments	KNm	-13.0	88.0	142.0	241.0	313.0	354.0	357.0
Stress at Girder Top, s_{tg}	KN/m^2	-22.1	149.4	241.1	409.1	531.3	600.9	606.0
Stress at Girder Bottom, s_{bg}	KN/m^2	10.4	-70.6	-113.9	-193.4	-251.2	-284.1	-286.5

5.7.12.1 Cumulative Stresses after Live Loads

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Stress at Girder Top, s_{tg}	KN/m^2	-1149	1373	340	3471	5709	7048	7477
Stress at Girder Bottom, s_{bg}	KN/m^2	2941	1763	7963	6546	5532	4926	4733

5.7.13 Losses in prestress (56.1 - Infinity days)

5.7.13.1 Relaxation loss (56.1 - Infinity days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Prestressing force up to 56.1 days.	KN	3538.0	3558.8	11986.1	12078.7	12144.8	12184.5	12197.7
Initial Stress as % of UTS (f_p)	f_p	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Relaxation loss for low relaxation steel at 1000 hrs.	%	3.500	3.500	3.500	3.500	3.500	3.500	3.500
Time after prestressing	hr.	Infinity						
Relaxation loss as % of loss at 1000 hrs.	%	300						
Relaxation loss for 56.1 to Infinity days	KN	(300 - 100.109) % x 1 x 3.5 % x 3910.5						
	KN	273.6	273.6	984.9	984.9	984.9	984.9	984.9

5.7.13.2 Shrinkage loss (56.1 - Infinity days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Residual Shrinkage Strain at	56 days	0.00018						
Residual Shrinkage Strain at	Infinity	0.00000						
Shrinkage loss for 56.1 to Infinity days	KN	= (0.000175 - 0) * 20 * 140* 195000 * 1/1000						
	KN	95.6	95.6	344.3	344.3	344.3	344.3	344.3

5.7.13.3 Creep loss (56.1 - Infinity days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Creep Strain / 10 Mpa at	56 days	0.00038						
Creep Strain / 10 Mpa at	Infinity	0.00000						
Creep Loss	KN	52	33	504	425	369	336	325
Total Loss (Relaxation + Shrinkage + Creep)	KN	421	402	1833	1754	1698	1665	1654
Stress after (R + S + C) loss								
Stress at Girder Top, s_{tg}	KN/m^2	131	125	568	544	527	516	513
Stress at Girder Bottom, s_{bg}	KN/m^2	-347	-332	-1511	-1446	-1400	-1372	-1364

5.7.13.4 Cumulative Stress after R + S + C loss (56.1 - Infinity days)

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Stress at Deck Top, s_{td}	KN/m^2	107	487	1163	1579	1879	2055	2095
Stress at Girder Top, s_{tg}	KN/m^2	-1019	1498	908	4015	6236	7565	7990
Stress at Girder Bottom, s_{bg}	KN/m^2	2594	1431	6452	5099	4132	3554	3369
Average Stress at Deck Top, s_{td}	KN/m^2	42	425	879	1307	1615	1796	1839
AverageStress at Girder Top, s_{tg}	KN/m^2	-1084	1436	624	3743	5972	7307	7733
AverageStress at Girder Bottom, s_{bg}	KN/m^2	2768	1597	7207	5822	4832	4240	4051
Stress at CG of Tendon	KN/m^2	2476	1585	6709	5665	4918	4472	4329
Iteration value	=	52	33	504	425	369	336	325
Difference	=	0	0	0	0	0	0	0

5.7.14 Total time dependent Losses + Elastic Shortening Loss in cables

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Elastic Shortening Loss	KN	53	41	614	564	527	506	498
% Loss	%	1.34	1.06	4.36	4.00	3.75	3.59	3.54
Relaxation Loss	KN	411	411	1478	1478	1478	1478	1478
% Loss	%	10.50	10.50	10.50	10.50	10.50	10.50	10.50
Shrinkage Loss	KN	235	235	845	845	845	845	845
% Loss	%	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Creep Loss	KN	95	67	987	867	781	729	713
% Loss	%	2.44	1.72	7.01	6.16	5.55	5.18	5.06
Total Loss (ESL + RL + SL + CL)	KN	793	754	3925	3754	3631	3558	3534
% Loss	%	20.29	19.28	27.88	26.66	25.80	25.28	25.11

5.7.15 20% extra time dependent loss

20% extra time dependent loss is taken to consider the effect of unsymmetrical section and other miscellaneous items to be on conservative side.

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Total time dependent Losses	kN	741	713	3310	3190	3104	3053	3036
20% extra time dependent loss	kN	148	143	662	638	621	611	607
Stress at Girder Top, s_{tg}	KN/m^2	46	44	205	198	193	189	188
Stress at Girder Bottom, s_{bg}	KN/m^2	-122	-117	-546	-526	-512	-503	-501

5.7.16 Effect of Loss due to 20% Extra Time Dependent Loss with Live Load

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Stress at Girder Top, s_{tg}	KN/m^2	-973	1542	1114	4213	6428	7754	8178
Stress at Girder Bottom, s_{bg}	KN/m^2	2472	1314	5906	4573	3620	3050	2868

5.7.17 Effect of Loss due to 20% Extra Time Dependent Loss without Live Load

Item	Unit	Support	Debonded	0.1L	0.2L	0.3L	0.4L	0.5L
Dist. from brg c/L	m	0.00	1.50	2.56	5.12	7.68	10.24	12.80
Stress at Girder Top, s_{tg}	KN/m^2	-951	1393	873	3804	5897	7153	7572
Stress at Girder Bottom, s_{bg}	KN/m^2	2462	1384	6020	4767	3872	3334	3155

5.8 Verification of Stresses at Top and Bottom Fibers

As per clause 3.2.2 of IRC: SP: 71 – 2006, Permissible stresses at top of the precast girder at service stage may be allowed to go into tension at the locations where top section is designed as reinforced concrete section, which is a common practice in case of precast pretensioned girders made continuous using cast-in-situ RCC deck slab and diaphragm. However, tensile stresses at the top of precast pretensioned girder shall be limited to 0.36 sqrt(fck). Also, the compressive stress in concrete under service loads shall not exceed 0.33 fck.

As per clause 3.2.1 of IRC: SP: 71 – 2006, following the clause 7.1 of IRC: 18 – 2000, the compressive stress produced due to loading shall not exceed 0.5 fcj which shall not be more than 20 MPa, where fcj is the concrete strength at that time subject to a maximum value of fck. The temporary tensile stresses in extreme fiber of concrete shall not exceed $1/10^{th}$ of the permissible temporary compressive stress in concrete.

Permissible stresses at Construction and Service Stages are as under:

Temporary Stage

Permissible compressive stress in temporary condition-in girder	=	17500	kN/m^2
Permissible tensile stress in temporary condition-in girder	=	-1750	kN/m^2

Service Stage

Permissible tensile stress in service condition-in girder top	=	-2670	kN/m^2
Permissible compressive stress in service condition-in girder	=	18150	kN/m^2

Stages	Age of Conc.	Allowable Stress			Girder Top Stress		Girder Bot Stress		Status	
		max +ve	max -ve							
		U Girder	Girder Top	Girder Bottom	max +ve	max -ve	max +ve	max -ve		
	days	KN/m2	KN/m2	KN/m2	KN/m2	KN/m2	KN/m2	KN/m2		
Temporary Stage										
Stress just after prestressing	3	17500	-1750	-1750	3395	-1404	9628	2357	OK	OK
Stress just before casting of track plinth	28	17500	-1750	-1750	3721	-1126	8688	2175	OK	OK
Stress after casting of track plinth	28	17500	-1750	-1750	5871	-1132	8324	1953	OK	OK
Stress after release of shuttering for track plinth	42	17500	-1750	-1750	5895	-1126	8257	1937	OK	OK
Stress after fixing of rails and other SIDL	56	17500	-1750	-1750	6874	-1126	8067	1832	OK	OK
Service Stage										
Stress without Live Load	infinity	18150	-2670	0	7572	-951	6020	1384	OK	OK
Stress with Live Load	infinity	18150	-2670	0	8178	-973	5906	1314	OK	OK

For Stress at bottom fiber – As the construction activity proceeds, the bending moment at bottom increased due to increase in load. Hence extra negative stresses induced at bottom, which counters the compressive stress due to prestressing.

CHAPTER 6 TRANSVERSE ANALYSIS

6.1 Principle of calculation

Transverse analysis is the analysis of U – Girder along transverse direction to the span length. This is used to determine the amount of flexural reinforcement in the deck slab. Transverse analysis is carried out using Staad Pro v8i software and excel spread sheets.

Followings steps are used for transverse analysis:

6.2 Modeling of Structure

The U – Girder has been modelled in three ways:

1. 2D model of 1m width.
2. 3D model of 1m width.
3. 3D model of whole span.

In 2D model of 1m width, centerline modelling of all the fibers is done in Staad by importing the structure from auto cad. Average thickness of all the elements is adopted for self-weight command. The Staad output for reaction of self-weight is cross-checked to verify the cross-sectional properties.

3D model of 1m width, is adopted to verify the concept of 2D line segment method. Both the models will give the same output results. In this model the U – Girder is divided in finite elements along and across the 1m span length. The exact thickness of all finite plates is assigned. The Staad output for reaction of self-weight is cross-checked to verify the cross-sectional properties.

3D model of whole span, is adopted to get the more exact output. Stress contours can be read from this model to understand the behavior of whole span. The whole U – Girder shall be modeled as plate structure of finite sizes. The plate structure is represented by the median fiber of the real plate, and by the thickness of the plate. All the loads applied on the surface of plate shall be diffused to the level of median fiber of plates.

Modelling of all the three types of models are described below and their Staad Input is attached as annexure.

6.2.1 2D model of 1m width

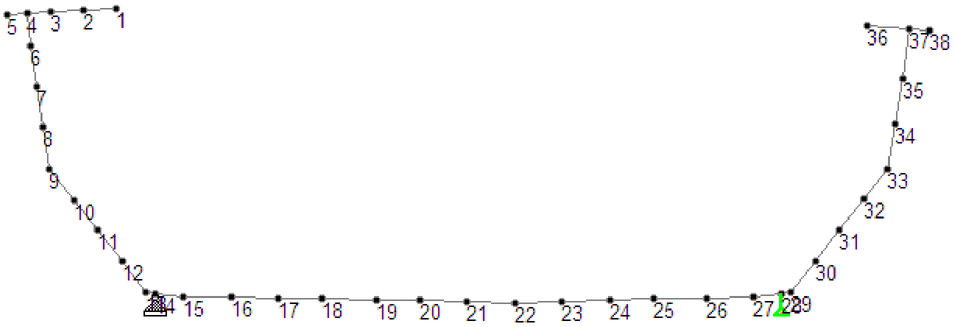


Figure 6.1 2D model of 1m width (Cross-section showing node nos.)

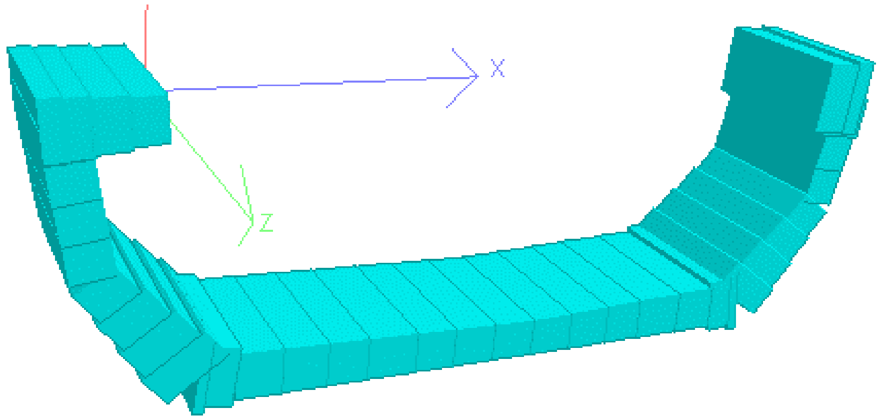


Figure 6.2 2D model of 1m width (3D view showing members thicknesses)

6.2.2 3D model of 1m width

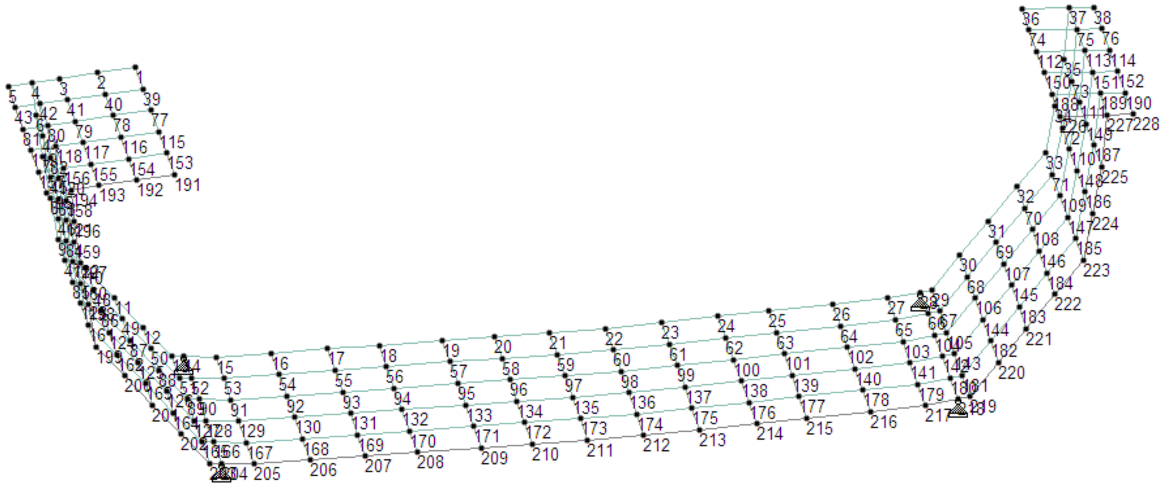


Figure 6.3 3D model of 1m width (Cross-section showing node nos.)

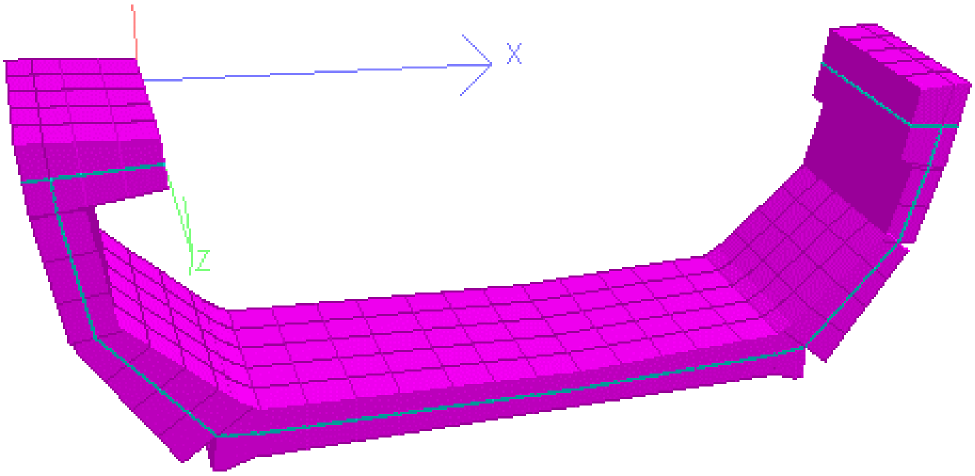


Figure 6.4 3D model of 1m width (Cross-section showing plates thicknesses)

6.2.3 3D model of whole span

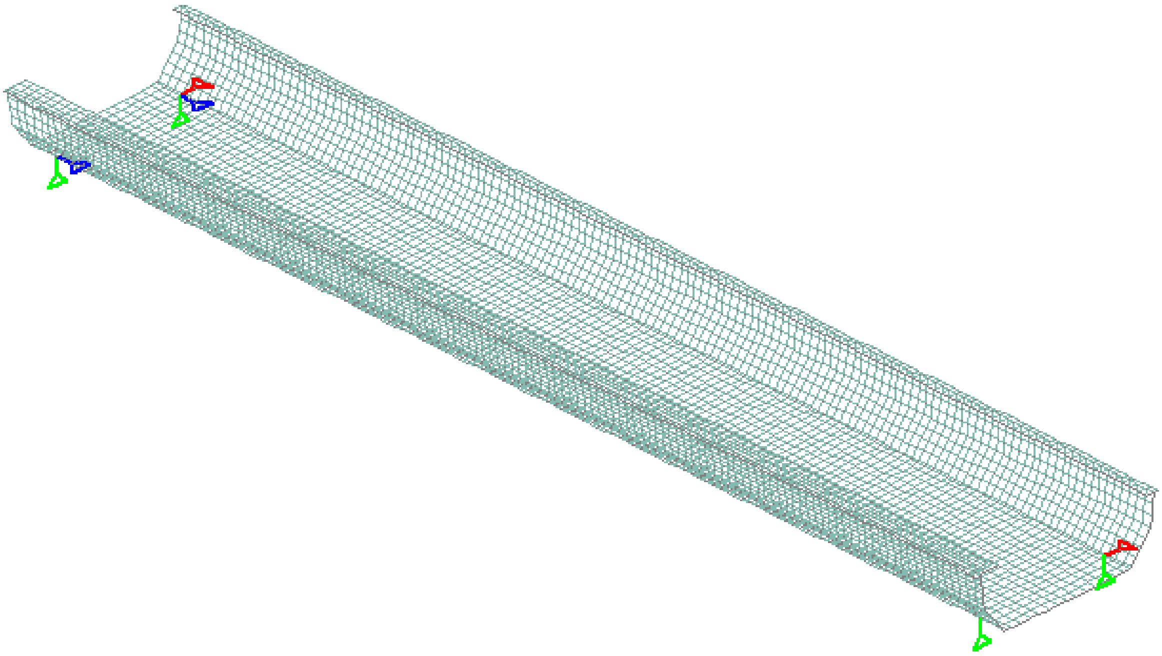


Figure 6.5 3D model whole span

6.3 Loads on U – Girder

6.3.1 Dead Load

The dead load is the self-weight of the structure. It shall be applied automatically by Staad using self-weight command.

As the cross sectional area of U – Girder is 2.173m^2 approx.

Therefore, dead load per unit meter length = 2.173 x 2.5 = 5.44 t/m.

6.3.2 Super Imposed Dead Load (SIDL)

SIDL shall be taken as per the Design Basis Report of DMRC for Various structural components.

Details of SIDL for two tracks:

Cables	0.07 t/m
Cable troughs with cover	0.74 t/m
Cable trays	0.01 t/m
Concrete plinths for rails + Rail + Pad	3.10 t/m
Miscellaneous (OCS, signaling,)	0.40 t/m
Hand Rail	0.08 t/m

Total: 4.4 t/m for two tracks
2.2 t/m for one track (one small U)

Say 45 kN/m for two tracks
22.5 kN/m for one track

In longitudinal direction, SIDL shall be applied on the total length of the U – Girder.

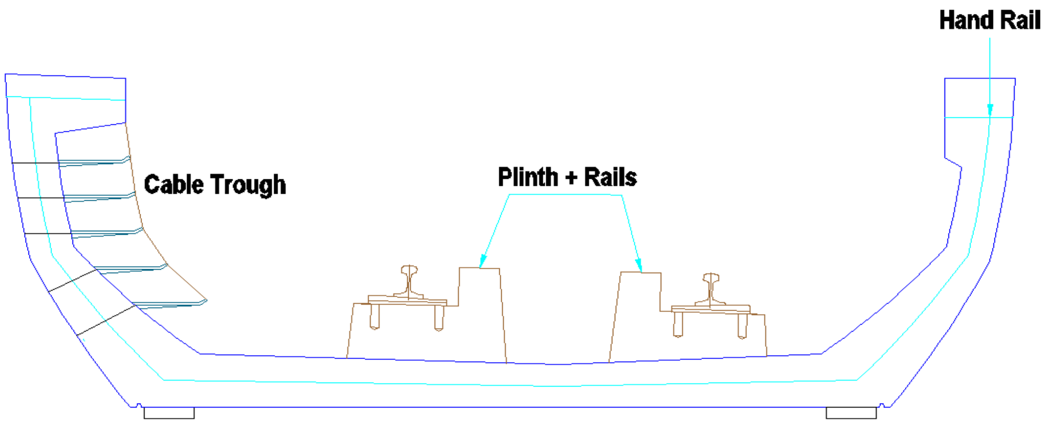


Figure 6.6 Locations of SIDL

In Transverse direction, dispersion of load up to median fiber shall be considered.

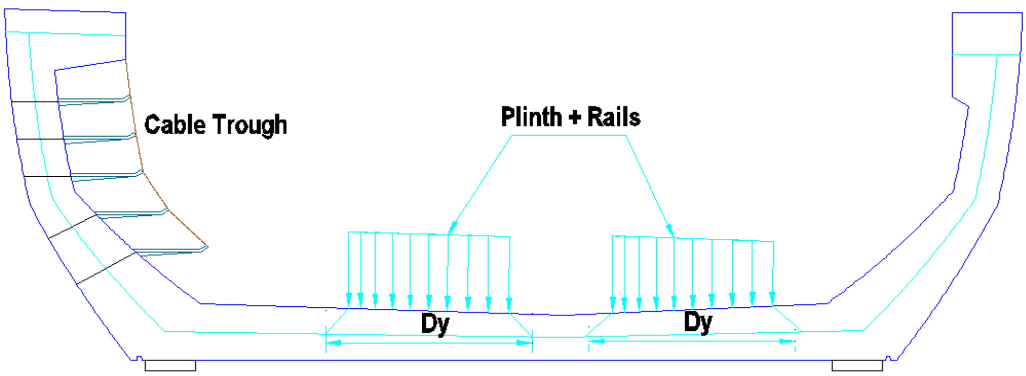


Figure 6.7 Dispersion of Plinth + Rail Load to Median Fiber

Dispersion width for self-weight of plinths and rails in trans. direction: Dy = 0.795m

The distributed load for two tracks: -

Concrete Plinths for Rails + Pads = 3.1 t/m (Due to 4 plinths)

Miscellaneous (OCS, Signaling) = 0.4 t/m

Total = 3.5 t/m

Therefore, distributed load in transverse direction = 3.5/4/0.790 = 1.11 t/m

Similarly, diffusion of cable trough is taken as equivalent vertical load and moment at the U – Girder webs.

Load due to Cables = 0.07 t/m

Cable troughs with cover = 0.74 t/m

Cable Trays = 0.01 t/m

Total = 0.82 t/m (for two tracks)

Therefore, vertical load on web at five positions (say) = 0.82/2/5 = 0.082 t/m.

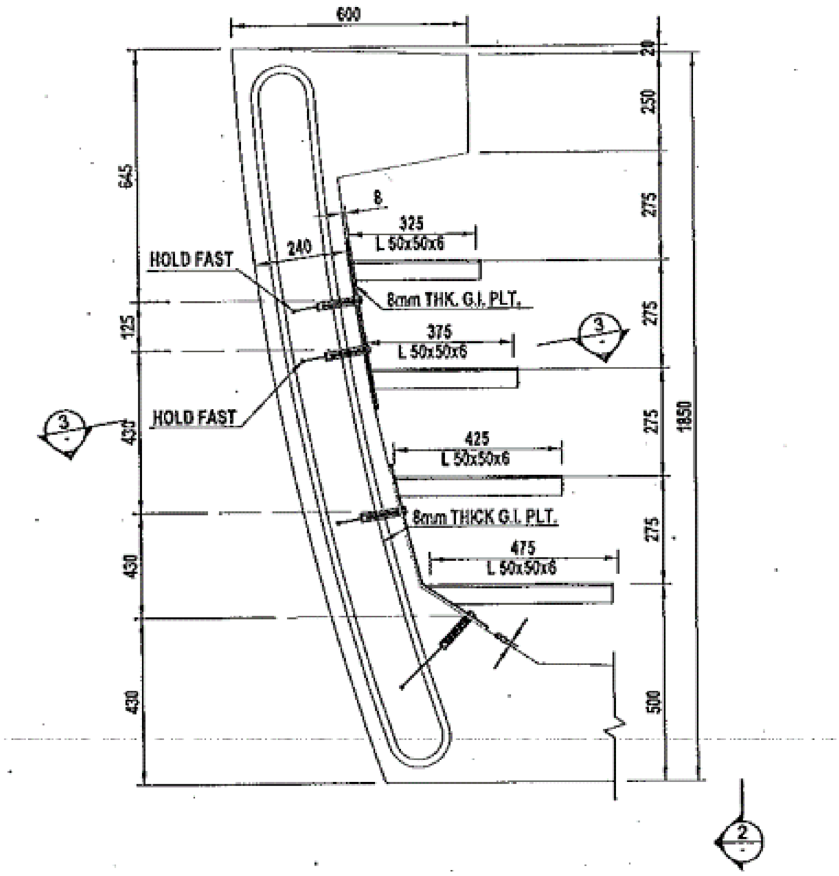


Figure 6.8 Detail of Cable Tray

Moment at face of web due to cable trays can be calculated as:

Wt. of 50x50x6mm angle	=	4.5	kg/m
Wt. of 1st angle, 325mm long	=	1.5	kg
Moment at connection	=	0.08	kgm
Wt. of 2nd angle, 375mm long	=	1.7	kg
Moment at connection	=	0.11	kgm
Wt. of 3rd angle, 425mm long	=	1.9	kg
Moment at connection	=	0.14	kgm
Wt. of 4th angle, 475mm long	=	2.1	kg
Moment at connection	=	0.17	kgm
Max. moment at any location	=	0.17	kg/m
Total wt. of angles	=	7.2	kg
Applying 0.17 kgm moment at each locations on conservative side.			

Similarly, Hand Rail load = 0.08 t/m (for two tracks)

i.e. 0.04 t/m load is applied on right side web as shown in fig. below.

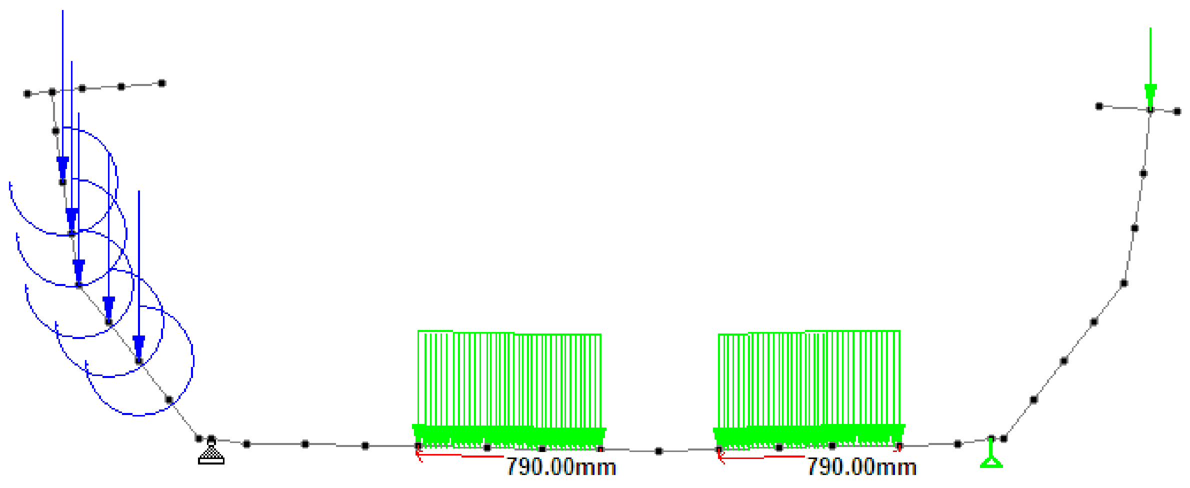


Figure 6.9 Application of SIDL

6.3.3 Live Load (LL)

Live load is the case that the wheels of car apply on the rails. The force of one wheel applied on rail is considered as concentrated forces. Then, it shall be distributed through the rail and plinth to the median fiber of the deck slab.

IRC: 21 – 2000 clause 305.16, specifies the effect of Live Load on deck slabs.

Deck slab is spanning between the two rigid web flanges and act as a solid slab spanning in one transverse direction. Thus, for a single concentrated load, the effective width may be calculated in accordance with the following equation:

$$bef = \alpha\, a\, (1 - a / l_0) + b_1$$

Where, bef = the effective width of slab on which the load acts

l_0 = the effective span

a = distance of C.G. of concentrated load from the nearer support

b1 = the breadth of concentration area of load transverse to span

α = a constant depending upon b / l_0 where b is the width of slab

	beff	=	**α a (1 - a / lo) + b1**			
For wheel 1 (Left)	α	=	2.6			
	a	=	1.200	m is the distance of wheel load from nearer support		
	lo	=	3.410	m		
	b1	=	0.840	m is the effective contact width of wheel load (2x(rail+plinth block)) in traffic direction		
	beff	=	**2.862**	>	2.5	m
	Therefore, beff	=	**(2.86+2.5)/2 =**		2.68	m
Equivalent UDL		=	2.98	t/m		
UDL with Impact factor		=	**4.98**	t/m	(With Impact factor = 1.67)	
For wheel 2 (Right)	α	=	2.6			
	a	=	0.700	m is the distance of wheel load from nearer support		
	lo	=	3.410	m		
	b1	=	0.840	m is the effective contact width of wheel load (2x(rail+plinth block)) in traffic direction		
	beff	=	**2.29**	<	2.5	m
	Therefore, beff	=	2.29	m		
Equivalent UDL		=	3.72	t/m		
UDL with Impact factor		=	**6.21**	t/m	(With Impact factor = 1.67)	

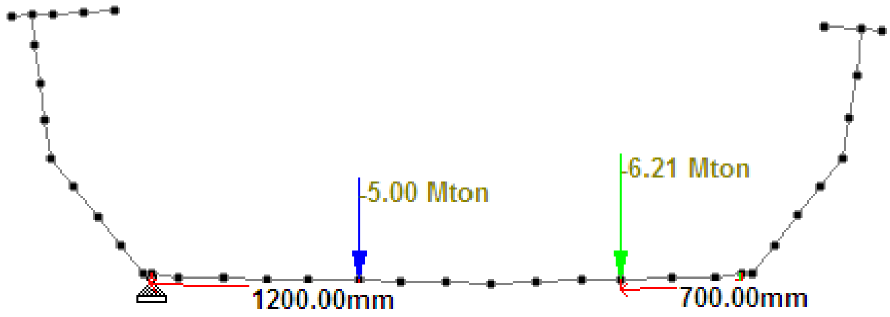


Figure 6.10 Dispersed Live Load per m width in 2D model

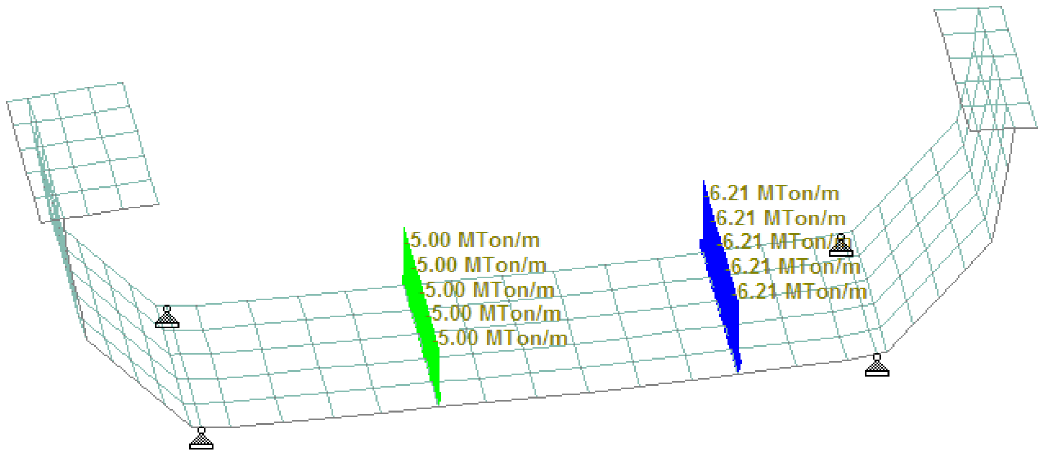


Figure 6.11 Dispersed Live Load per m width in 3D model

Position of live load in longitudinal direction

In general, the analysis of structure at each section requires determining the most unfavorable position of the live load which introduces the extreme effect to the structure.

In this analysis, the sections selected to design are section at mid span and section right near the bearings. Thus, there are two cases of live load taken into consideration, as follow:

Case 1: 4 axles of cars on the middle span. This case will introduce the maximum effect at the section at mid-span.

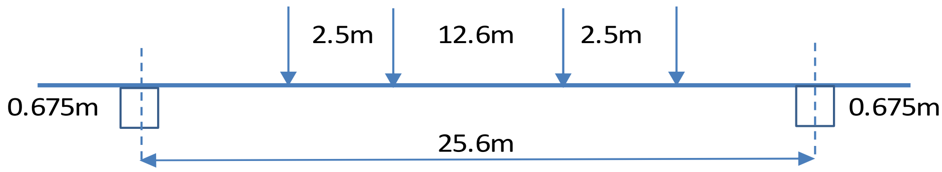


Figure 6.12 Case 1: Live Load in longitudinal direction

Case 2: 6 axles of cars on the span. This case will introduce the maximum effect of the section near bearing.

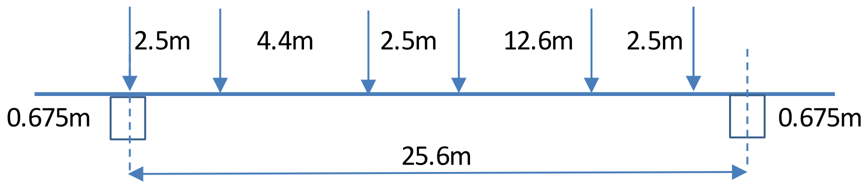


Figure 6.13 Case 2: Live Load in longitudinal direction

For the analysis of U – Girder using 3D model of whole span, both the above cases are used to check the stresses at mid span and end of span.

6.4 Slab Transverse Flexure Calculation

Transverse bending of deck slab is analyzed from all the three models and output results are compared. Slab is designed for maximum bending moment of the three models in ULS case and cross checked for crack width in SLS case.

6.4.1 ULS Calculation

The load combination for ULS case is taken from Design Basis Report of DMRC.

ULS combination: 1.25 DL + 2 SIDL + 1.75 LL

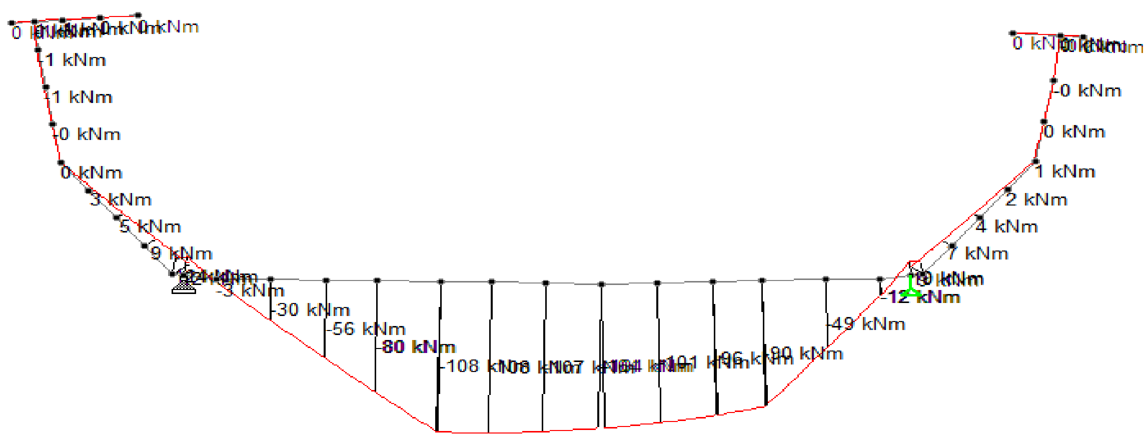


Figure 6.14 BMD for ULS – 2D Model of 1m Width

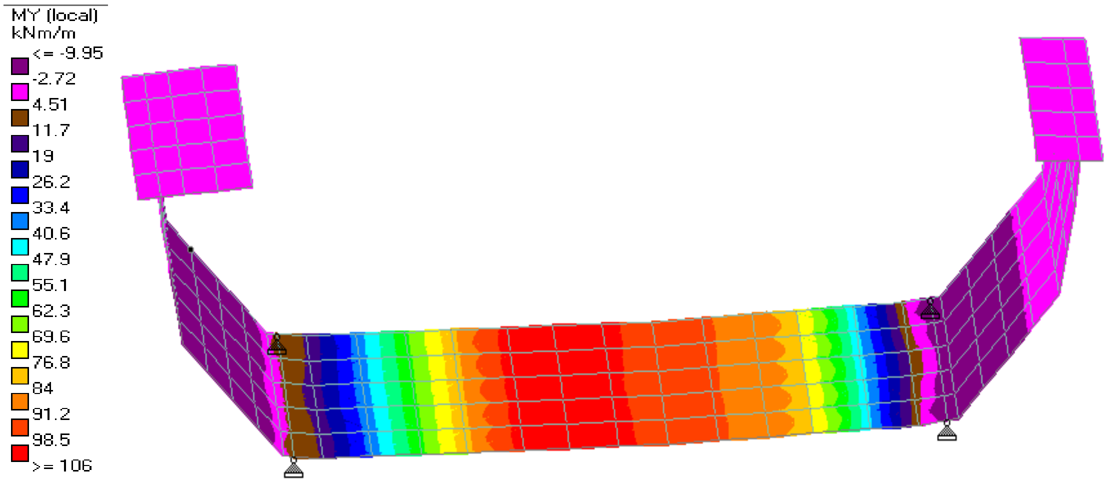


Figure 6.15 BMD for ULS – 3D Model of 1m Width

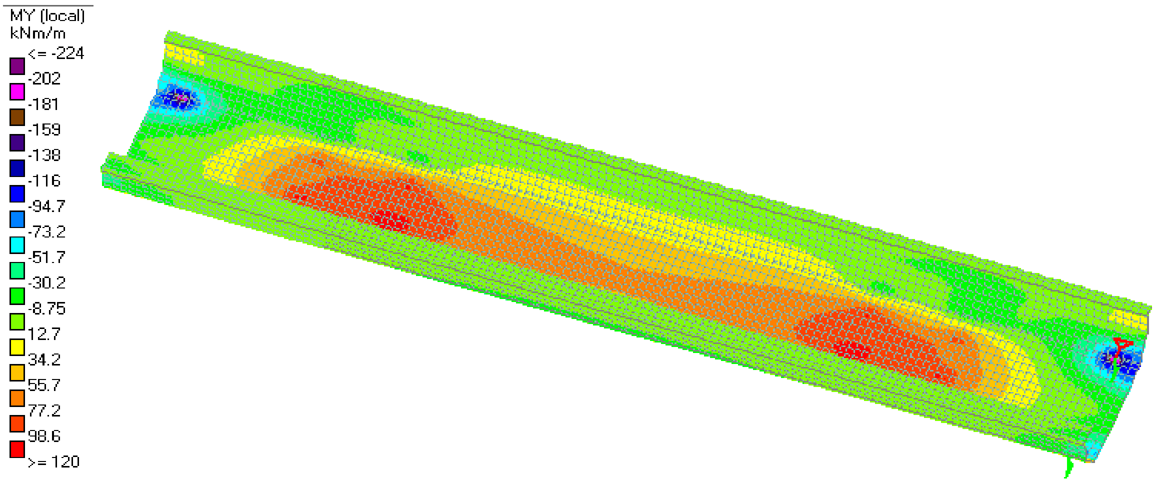


Figure 6.16 BMD for ULS – 3D Model of Whole Span (Mid)

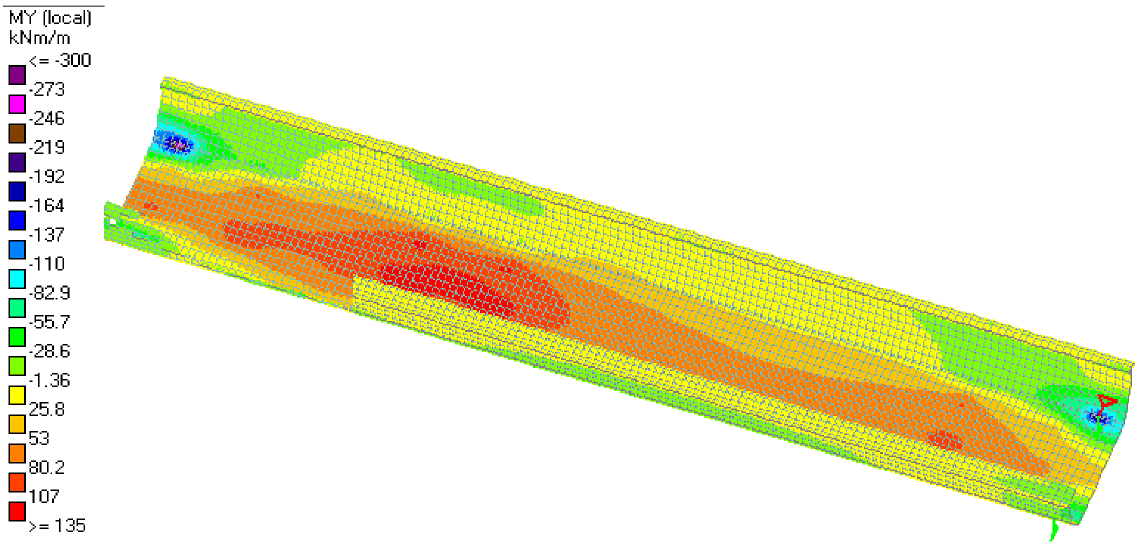


Figure 6.17 BMD for ULS – 3D Model of Whole Span (End)

6.4.1.1 ULS Bending Moment Summary

Load Case	Type of model	Moment at deck center (tm)
ULS	2D	10.80
	3D 1m wide	10.60
	3D whole (At mid span)	12.00
	3D whole (At End of span)	13.40
	Design Moments	**13.40**

It can be seen from above output summary that 2D and 3D models of 1m width results the same values and 3D model of whole span gives slightly higher values. This is due to addition of longitudinal stresses together with transverse stresses.

Considering the highest value, the design bending moment for deck slab = 13.4 tm.

6.4.1.2 Required Reinforcement from ULS

ULS load combination is used to determine the area of reinforcement for flexure.

Required area of reinforcement can be calculated as,

$$Ast.req = 0.5fck/fy \times \{1 - (1 - 4.6Mu/fckbd^2)^{0.5}\} \times bd$$

fck	=	55	Mpa
fy	=	500	Mpa
b	=	1000	mm
d	=	240-40-20/2 =	190 mm
Ast.req	=	**1787**	mm2
Ast, provided	=	20 dia @ 125 c/c spacing	
	=	**2512**	**mm2 and hence OK**

6.4.2 SLS Calculation

SLS combination: 1.0 DL + 1.2 SIDL + 1.1 LL

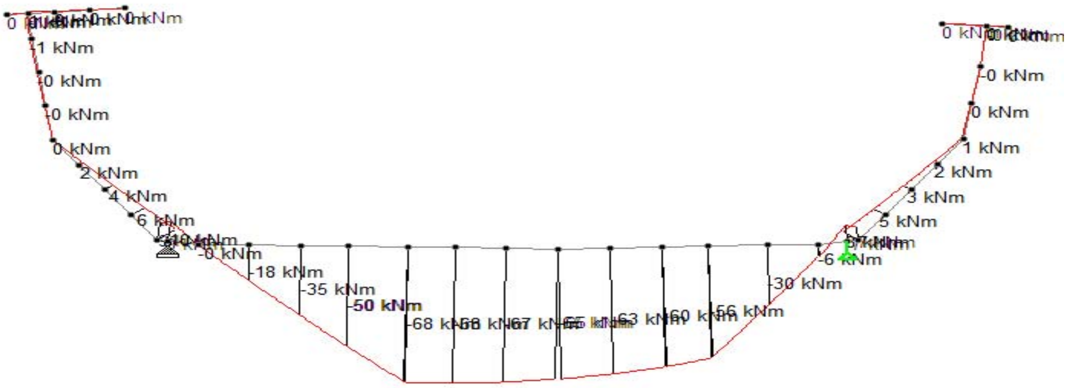


Figure 6.18 BMD for SLS – 2D Model of 1m Width

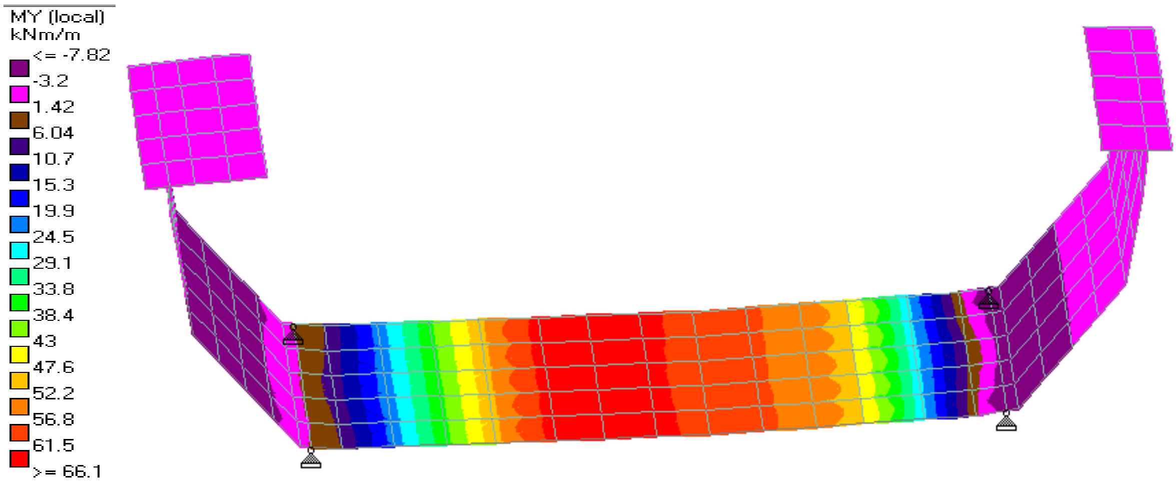


Figure 6.19 BMD for SLS – 3D Model of 1m Width

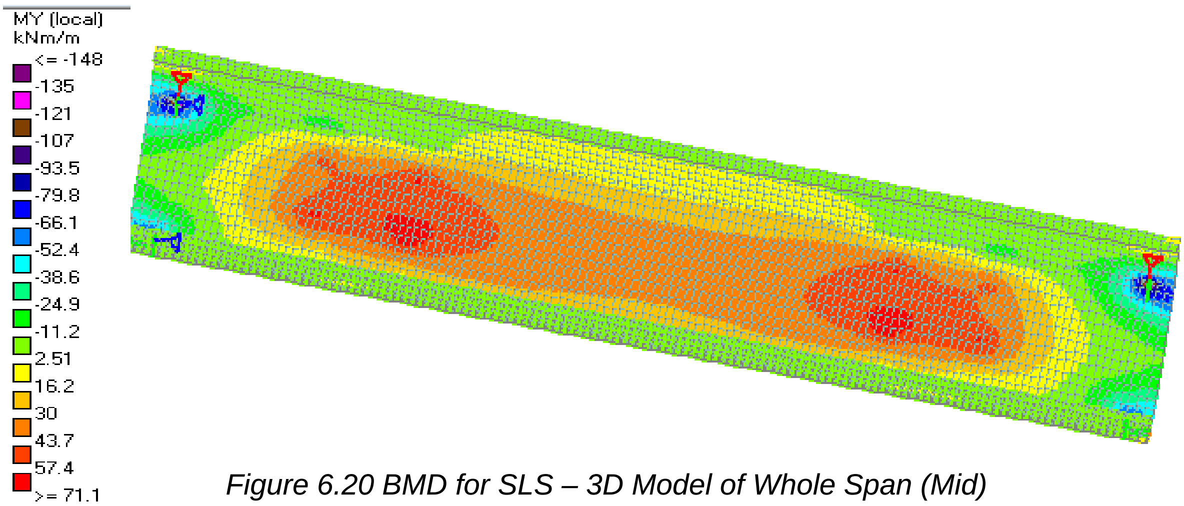


Figure 6.20 BMD for SLS – 3D Model of Whole Span (Mid)

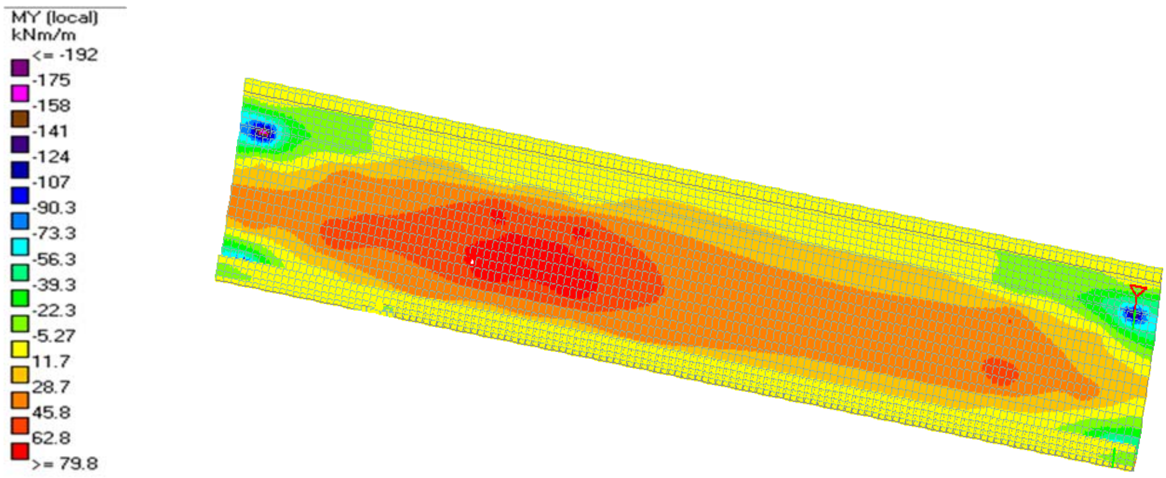


Figure 6.21 BMD for SLS – 3D Model of Whole Span (End)

6.4.2.1 SLS Bending Moment Summary

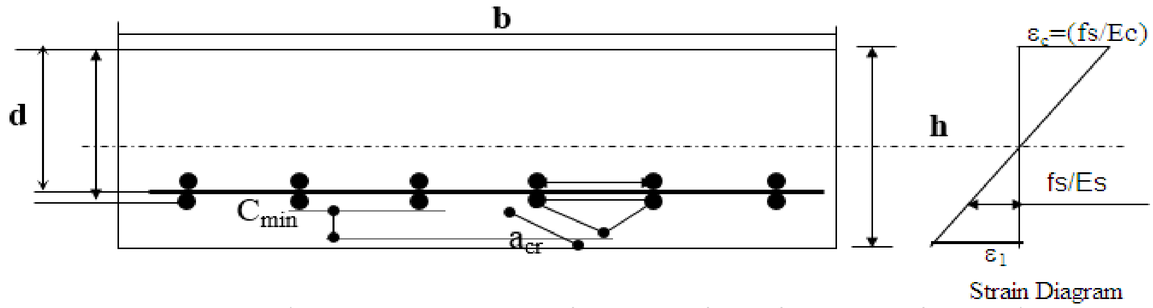
Load Case	**Type of model**	**Moment at deck center (tm)**
SLS	2D	6.85
	3D 1m wide	6.61
	3D whole (At mid span)	7.11
	3D whole (At End of span)	7.98
	Design Moments	**7.98**

It can be seen from above output summary that 2D and 3D models of 1m width results the same values and 3D model of whole span gives slightly higher values. This is due to addition of longitudinal stresses together with transverse stresses.

Considering the highest value, the design bending moment for deck slab = 7.98 tm.

6.4.2.2 Required Reinforcement from SLS

SLS load combination is used to determine the area of reinforcement from stress check and crack width control. The crack width is restricted to 0.2mm and is calculated as per clause 35.3.2 and 43.1 of IS: 456 – 2000.



Serviciability State Moment,		M_s	=	**79.8**	kNm/m
Serviciability State Axial Force (conservative side)		P	=	**0**	kN
C/C bar Spacing of Tension Reinforcement		s	=	**125**	mm
Diameter of Tension Reinforcement Bars 1^{st} Layer		ϕ_1	=	**20**	mm
Diameter of Spacer Bar		ϕ_s	=	**0**	mm
Diameter of Tension Reinforcement Bars 2^{nd} Layer		ϕ_2	=	**0**	mm
Nominal Cover to 1^{st} layer of reinforcement		n_c	=	**40**	mm
Diameter of Link Bar		L_{bar}		**0**	mm
Width of Section		b	=	**1000**	mm
Total depth of member		h	=	**240**	mm
Dist' from comp' face to the point at which the crack is being cal'd, Usually 'h' if crack on tension face		a	=	240	mm
Minimum clear cover to tension reinforcement		c_{min}	=	**40**	mm
Width of section at centroid of tension reinforcement		b_t	=	1000	mm
Characteristic strength of concrete, 28 day cube strength		$f_{ck,28}$	=	**55**	N/mm²
Characteristic strength of reinforcement bar		f_y	=	**500**	N/mm²
Concrete modulus (28 day), IS 456 : CL : 6.2.3.1	$E_{c,28} = 5000\sqrt{f_{ck}}$	$E_{c,28}$	=	37081.0	N/mm²
Steel modulus		E_s	=	**200000**	N/mm²
Area of Tension Reinforcement		A_s	=	2513	mm²
Tension reinforcement proportion *i.e.*	p=As/(b*d)	p	=	0.0132	
Eff. Depth of Tension Reinf.,	$d=h-nc-L_{bar}-\phi_1/2$ **or** $d=h-nc-L_{bar}-\phi_1-\phi_s/2$	d	=	190.0	mm
Creep coefficient	IS 456 : CL : 6.2.5.1	θ	=	**1.10**	
Eff. Modulus of the concrete,	$E_{eff}= E_c / (1+\theta)$	E_{eff}	=	17658	N/mm²
Modular ratio, for cracked section	$m = E_s/E_{eff}$	m	=	11.33	
Therefore		m*p	=	0.150	
Ratio of Neutral axis depth to Eff. Depth	$x/d=\sqrt{[p^2m^2+2(mp)]}-m*p$	k=x/d	=	0.418	
Depth to neutral axis	x=k*d	x	=	79.4	mm
Lever arm	z = d-x/3	z	=	163.5	mm
Stress in tension steel $f_s=[M_s / (A_s*z)]$ should be < $0.75*f_y$		f_s	=	194.1	N/mm²
Compressive Stress in concrete $f_{cb}=2M_s/(z*b*x)$ should be<$0.4f_{ck}$		f_{cb}	=	12.3	N/mm²

Strain at the level considered, calculated ignoring the stiffening effect
of concrete in the tension zone, IS 456 : ANNEX F $\varepsilon_1=(f_s/E_s)(a-x)/(d-x)$ ε_1 = 0.00141

Strain at the level considered, calculated considering the stiffening effect
of concrete due to Axial load, $\varepsilon_2 = ((P/b*h)/E_{eff})$ ε_2 = 0.00000

Net effective Strain
e'_1 $\varepsilon'_1 = \varepsilon_1 - \varepsilon_2$ ε'_1 = 0.00141

Distance from critical crack position to surface of rebar
max' crack width occurs midway between the bars on tension face a_{cr} = 70.0 mm

Average strain at level where crack is considered ε_m = 0.00125

$\varepsilon_m = \varepsilon'_1 - [b_t(h-x)(a-x)/(3E_sA_s(d-x))]$

SURFACE CRACK WIDTH

$w = (3a_{cr}\varepsilon_m)/(1+2((a_{cr} - c_{min})/(h-x)))$ **Wcr = 0.192 mm** > **0.2 mm**

The summary of stress in concrete Fc, stress in steel Fs and crack width is shown below, along with their permissible limits.

Fc (Mpa)	*Fs (Mpa)*	*CRACK WIDTH (mm)*	*ALLOWABLE, Fc (Mpa)*	*ALLOWABLE, Fs (Mpa)*	*ALLOWABLE CRACK WIDTH, (mm)*	*REMARK*
12.3	194.1	0.192	22	375	0.2	***OK***

CHAPTER 7 RESULTS AND DISCUSSION

Longitudinal analysis was performed to find the stresses at extreme fibers of U – Girder. The following results are obtained:

Stages	Age of Conc.	Allowable Stress			Girder Top Stress		Girder Bot Stress		Status	
		max +ve	max -ve							
		U Girder	Girder Top	Girder Bottom	max +ve	max -ve	max +ve	max -ve		
	days	KN/m^2	KN/m^2	KN/m^2	KN/m^2	KN/m^2	KN/m^2	KN/m^2		
Temporary Stage										
Stress just after prestressing	3	17500	-1750	-1750	3395	-1404	9628	2357	OK	OK
Stress just before casting of track plinth	28	17500	-1750	-1750	3721	-1126	8688	2175	OK	OK
Stress after casting of track plinth	28	17500	-1750	-1750	5871	-1132	8324	1953	OK	OK
Stress after release of shuttering for track plinth	42	17500	-1750	-1750	5895	-1126	8257	1937	OK	OK
Stress after fixing of rails and other SIDL	56	17500	-1750	-1750	6874	-1126	8067	1832	OK	OK
Service Stage										
Stress without Live Load	infinity	18150	-2670	0	7572	-951	6020	1384	OK	OK
Stress with Live Load	infinity	18150	-2670	0	8178	-973	5906	1314	OK	OK

It can be seen that as the construction activity proceeds, the bending moment at bottom fiber increased due to increase in load. Hence extra negative stresses induced at bottom, which counters the compressive stress due to prestressing.

Thus, the reduction in compressive stress at bottom fiber from 9628 KN/m^2 to 5906 KN/m^2 explain the concept of prestressing.

Similarly, at the top fiber, the compressive stresses increases from 3395 KN/m^2 to 8178 KN/m^2.

In case of prestressed girders, the stresses induced at any stage of construction should not cross the permissible limits. Therefore, it becomes important to alalyse the girder at every stage of loading.

Transverse analysis of deck slab was performed to determine the reinforcement in flexure and the same was verified for stress limits and crack control. For this three types of Staad models were used to get the more accurate results.

The following results are obtained from ULS combination:

Load Case	**Type of model**	**Moment at deck center (tm)**
ULS	2D	10.80
	3D 1m wide	10.60
	3D whole (At mid span)	12.00
	3D whole (At End of span)	13.40
	Design Moments	**13.40**

It can be seen from above output summary that 2D and 3D models of 1m width results the same values and 3D model of whole span gives slightly higher values. This is due to addition of longitudinal stresses together with transverse stresses.

Considering the highest value, the design bending moment for deck slab = 13.4 tm.

Required area of reinforcement = 1787 mm^2

Provided area of reinforcement = 20 dia @ 125 c/c

= 2512 mm^2

The following results are obtained from SLS combination:

Load Case	**Type of model**	**Moment at deck center (tm)**
SLS	2D	6.85
	3D 1m wide	6.61
	3D whole (At mid span)	7.11
	3D whole (At End of span)	7.98
	Design Moments	**7.98**

Considering the highest value, the design bending moment for deck slab = 7.98 tm.

Stresses in concrete and steel are as under:

Fc (Mpa)	*Fs (Mpa)*	*CRACK WIDTH (mm)*	*ALLOWABLE, Fc (Mpa)*	*ALLOWABLE, Fs (Mpa)*	*ALLOWABLE CRACK WIDTH, (mm)*	*REMARK*
12.3	194.1	0.192	22	375	0.2	***OK***

It can be seen from above analysis that the reinforcement is governed by crack width.

CHAPTER 8 CONCLUSION

The objective of this project report was to study the various design aspects of the U-Girder Bridge and the level of their suitability for Metro Rapid Transit System. Advantages and disadvantages of U-Girders compared to other conventional systems. A detailed study was done to understand the construction complications along with the design of U – Girder.

It is found that the shape of U – Girder is best fit for Metro Rapid Transit System. The two webs remove the need of extra parapets for supporting OHE mast and walkway. The approximate cross sectional area of each U – Girder = 2.17m^2

Thus, the total amount of concrete used for a 27m span = 2 x 2.17 x 27 = 117m^3

On the other hand, for a conventional segmental box construction, approx. 150 m^3 concrete is required for box section only. For both the parapets, extra concrete = 2 x 0.65 x 27 = 35 m^3 is also required.

Thus, 117 / 185 x 100 = 65% of concrete is used.

Also, the amount of reinforcement required in U-Girder is approx. = 175 kg/m3.

Total required steel = 0.175 x 117 = 20.5 t.

On the other hand, total steel in a box girder is approx. = 29 + 4 = 33 t.

Thus, 20.5 / 33 x 100 = 62% of steel is used.

Also, the amount of prestressing required in U-Girder is approx. = 72 x 1.1 x 27 / 1000 = 4.3 t.

On the other hand, total HTS in a box girder is approx. = 33 x 150 /1000 = 4.95 t.

Thus, 4.3 / 4.95 x 100 = 87% of HTS is used.

Also, the depth of 2m in a segmental box is reduced by 250mm thick deck only. Thus reducing the height of each pier by 1.75m. For the piers of average height 10m, the reduction in cost is approx. = 1.75 / 10 x 100 = 17.5%

Item	Quantity in a segmental box girder of 27m span	Quantity in a U – Girder of 27m span	Saving of quantities
Concrete (m3)	185	117	35%
Steel (t)	33	20.5	38%
HTS (t)	4.95	4.3	13%

Also, due to the reduced weight of superstructure, the size of foundation is also reduced.

Due to the reduction in height of piers, the length of approaches are also reduced.

Thus, it can be concluded from the summary of quantities saved by U – Girder that overall cost of the project can be reduced by more than 20%.

Although, U – Girder is having lower cost of construction, it may sometimes not be feasible at every locations of the city. This is due to the problem of carrying a long precast slab with a treler of additional length of approximately 3 to 5m.

Also, a specialized casting yard of sufficient area is required in the vicinity of actual site of construction. And in the congested cities, it may not be feasible to find the amount of area required. For casting yards at longer distances, transportation may increase the cost of construction. Therefore, a proper planning of land availability and the amount of quantity saving is required to adopt any structural system.

8.1 Scope of Further Study

In can be seen from the above conclusions that the Pre-tensioned pre-cast U-Girder is unsuitable for longer span due to too much difficulty in execution and uneconomy. Therefore, for longer spans post-tensioned segmental manner is more suitable.

Also, the moment of inertia of open U – Girders is small as compared to closed box girders. Thus, for longer spans a combination of two structural systems could be a better option as shown below:

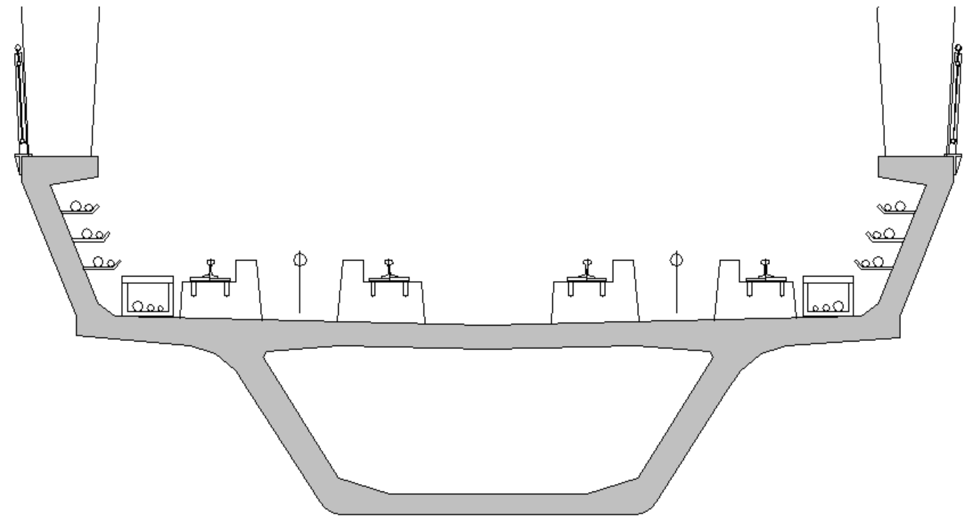


Figure 8.1 Post-Tensioned Segmental Box Monolithic with Parapets

Also, the by modifying the shape of web flanges, it may be used in road bridges etc.

For all kind of such uses a detailed planning of the region and analysis of various possible structural systems it required.

CHAPTER 9 REFERRENCES

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[4] Final detailed project report of Pune Metro Rail Project by DMRC for Pune Municipal Corporation.

[5] HEWSON N.R. Dubai LRT – Design of viaduct precast trough deck, Concrete: Construction's Sustainable Option (Ed. By Dhir R K).

[6] Design of Prestressed concrete structure by T. Y. Lin, John Wiley & Sons.

[7] IRS Concrete Bridge Code: 1997 – Code of Practice for Plain, Reinforced and Prestressed Concrete for General Bridge Construction.

[8] IRC: 18 – 2000 Design Criteria for Prestressed Concrete Road Bridges.

[9] IRC: SP: 71 – 2006 Guidelines for Design and Construction of Precast Pretensioned Girders for Bridges.

[10] IS: 14268 – 2003 Uncoated Stress Relieved Low Relaxation Seven Ply Strand for Prestressed Concrete - Specification.

[11] IS: 1343 - 2012 Prestressed Concrete – Code of Practice.

[12] IS: 456 – 2000 Plain and Reinforced Concrete – Code of Practice.

CHAPTER 10 ANNEXURE

10.1 Staad Input for Longitudinal Analysis

10.1.1 Behaviour of U – Girder under DL + SIDL

STAAD PLANE

START JOB INFORMATION

ENGINEER DATE 27-Mar-16

END JOB INFORMATION

INPUT WIDTH 79

UNIT METER KN

JOINT COORDINATES

1 0 0 0; 2 0.675 0 0; 3 2.175 0 0; 4 3.235 0 0; 5 5.7946 0 0; 6 8.3544 0 0;

7 10.9142 0 0; 8 13.474 0 0; 9 16.0338 0 0; 10 18.5936 0 0; 11 21.1534 0 0;

12 23.7132 0 0; 13 24.775 0 0; 14 26.275 0 0; 15 26.95 0 0;

MEMBER INCIDENCES

1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 5 6; 6 6 7; 7 7 8; 8 8 9; 9 9 10; 10 10 11;

11 11 12; 12 12 13; 13 13 14; 14 14 15;

DEFINE MATERIAL START

ISOTROPIC CONCRETE

E 2.17185e+007

POISSON 0.17

DENSITY 25

ALPHA 1.17e-005

DAMP 0.05

TYPE CONCRETE

STRENGTH FCU 55000

END DEFINE MATERIAL

MEMBER PROPERTY AMERICAN

1 TO 14 PRIS AX 2.173 IX 0.001 IY 0.001 IZ 0.74

CONSTANTS

MATERIAL CONCRETE ALL

SUPPORTS

2 PINNED

14 FIXED BUT FX MX MY MZ

LOAD 1 LOADTYPE None TITLE DEAD LOAD

SELFWEIGHT Y -1

```
LOAD 2 LOADTYPE None TITLE SIDL
MEMBER LOAD
1 TO 14 UNI GY -22.5
PERFORM ANALYSIS PRINT ALL
FINISH
```

10.1.2 Behaviour of U – Girder under Live Load

```
STAAD PLANE
START JOB INFORMATION
ENGINEER DATE 27-Mar-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 0.675 0 0; 3 2.175 0 0; 4 3.235 0 0; 5 5.7946 0 0; 6 8.3544 0 0;
7 10.9142 0 0; 8 13.474 0 0; 9 16.0338 0 0; 10 18.5936 0 0; 11 21.1534 0 0;
12 23.7132 0 0; 13 24.775 0 0; 14 26.275 0 0; 15 26.95 0 0;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 5 6; 6 6 7; 7 7 8; 8 8 9; 9 9 10; 10 10 11;
11 11 12; 12 12 13; 13 13 14; 14 14 15;
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 25
ALPHA 1.17e-005
DAMP 0.05
TYPE CONCRETE
STRENGTH FCU 55000
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
1 TO 14 PRIS AX 2.173 IX 0.001 IY 0.001 IZ 0.74
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
2 PINNED
14 FIXED BUT FX MX MY MZ
DEFINE MOVING LOAD
TYPE 1 LOAD 19.2 19.2 19.2 19.2 19.2 19.2 19.2 19.2
DIST 2.5 12.6 2.5 4.5 2.5 12.6 2.5
LOAD GENERATION 222
TYPE 1 -17.6 0 0 XINC 0.2
PERFORM ANALYSIS PRINT ALL
FINISH
```

10.2 Staad Input for Transverse Analysis

10.2.1 2D Model of 1m Width

STAAD PLANE DXF IMPORT OF FINAL.DXF

START JOB INFORMATION

ENGINEER DATE 21-Jun-16

END JOB INFORMATION

INPUT WIDTH 79

UNIT MMS MTON

JOINT COORDINATES

1 0 0 0; 2 -175.783 -12.0703 0; 3 -351.567 -24.1406 0; 4 -477.808 -32.809 0;

5 -592.546 -40.6875 0; 6 -465.302 -204.411 0; 7 -430.863 -428.38 0;

8 -396.425 -652.35 0; 9 -361.986 -876.32 0; 10 -230.07 -1044.67 0;

11 -98.1537 -1213.02 0; 12 33.7623 -1381.37 0; 13 165.678 -1549.72 0;

14 219.79 -1556.37 0; 15 370.685 -1575 0; 16 628.444 -1579.29 0;

17 886.204 -1583.57 0; 18 1125.14 -1587.86 0; 19 1420.11 -1592.14 0;

20 1659.48 -1596.43 0; 21 1915.04 -1600.71 0; 22 2175 -1605 0;

23 2434.93 -1599 0; 24 2696.73 -1593 0; 25 2929.79 -1587 0; 26 3224.72 -1581 0;

27 3479.31 -1575 0; 28 3629.79 -1556.42 0; 29 3684.32 -1549.72 0;

30 3815.52 -1381 0; 31 3946.73 -1212.28 0; 32 4077.93 -1043.56 0;

33 4209.14 -874.835 0; 34 4252.52 -632.014 0; 35 4295.89 -389.192 0;

36 4100 -99.9998 0; 37 4322.29 -116.351 0; 38 4437.47 -124.823 0;

MEMBER INCIDENCES

1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 4 6; 6 6 7; 7 7 8; 8 8 9; 9 9 10; 10 10 11;

11 11 12; 12 12 13; 13 13 14; 14 14 15; 15 15 16; 16 16 17; 17 17 18; 18 18 19;

19 19 20; 20 20 21; 21 21 22; 22 22 23; 23 23 24; 24 24 25; 25 25 26; 26 26 27;

27 27 28; 28 28 29; 29 29 30; 30 30 31; 31 31 32; 32 32 33; 33 33 34; 34 34 35;

35 35 37; 36 36 37; 37 37 38;

DEFINE MATERIAL START

ISOTROPIC CONCRETE

E 3.7

POISSON 0.17

DENSITY 2.5e-009

ALPHA 1.17e-005

DAMP 0.05

TYPE CONCRETE

STRENGTH FCU 0.0055

END DEFINE MATERIAL

MEMBER PROPERTY INDIAN
1 PRIS YD 268 ZD 1000
2 PRIS YD 304 ZD 1000
3 PRIS YD 334 ZD 1000
4 PRIS YD 355 ZD 1000
5 PRIS YD 230 ZD 1000
6 PRIS YD 230 ZD 1000
7 PRIS YD 230 ZD 1000
8 PRIS YD 230 ZD 1000
9 PRIS YD 253 ZD 1000
10 PRIS YD 305 ZD 1000
11 PRIS YD 361 ZD 1000
12 PRIS YD 418 ZD 1000
13 PRIS YD 450 ZD 1000
14 PRIS YD 375 ZD 1000
15 PRIS YD 296 ZD 1000
16 PRIS YD 287 ZD 1000
17 PRIS YD 279 ZD 1000
18 PRIS YD 270 ZD 1000
19 PRIS YD 262 ZD 1000
20 PRIS YD 253 ZD 1000
21 PRIS YD 245 ZD 1000
22 PRIS YD 246 ZD 1000
23 PRIS YD 258 ZD 1000
24 PRIS YD 270 ZD 1000
25 PRIS YD 282 ZD 1000
26 PRIS YD 294 ZD 1000
27 PRIS YD 375 ZD 1000
28 PRIS YD 450 ZD 1000
29 PRIS YD 418 ZD 1000
30 PRIS YD 361 ZD 1000
31 PRIS YD 308 ZD 1000
32 PRIS YD 256 ZD 1000
33 PRIS YD 230 ZD 1000
34 PRIS YD 230 ZD 1000
35 PRIS YD 280 ZD 1000
36 PRIS YD 483 ZD 1000
37 PRIS YD 523 ZD 1000

```
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
14 PINNED
28 FIXED BUT FX FZ MX MY MZ
LOAD 1 LOADTYPE None  TITLE LOAD CASE 1 : DEAD LOAD
SELFWEIGHT Y -1
LOAD 2 LOADTYPE None  TITLE LOAD CASE 2 : SIDL
MEMBER LOAD
18 TO 20 23 TO 25 UNI GY -0.00111
JOINT LOAD
7 TO 11 FY -0.082 MZ -0.17
37 FY -0.04
LOAD 3 LOADTYPE None  TITLE LOAD CASE 3 : LIVE LOAD
JOINT LOAD
19 FY -5
25 FY -6.21
LOAD COMB 4 COMBINATION LOAD CASE 4 : SLS LOAD COMBINATION
1 1.0 2 1.2 3 1.1
LOAD COMB 5 COMBINATION LOAD CASE 5 : ULS LOAD COMBINATION
1 1.25 2 2.0 3 1.75
PERFORM ANALYSIS
PRINT MEMBER FORCES LIST 12 20 29
PRINT SUPPORT REACTION ALL
FINISH
```

10.2.2 3D Model of 1m Width

STAAD SPACE DXF IMPORT OF FINAL.DXF

START JOB INFORMATION

ENGINEER DATE 21-Jun-16

END JOB INFORMATION

INPUT WIDTH 79

UNIT MMS MTON

JOINT COORDINATES

1 0 0 0; 2 -175.783 -12.0703 0; 3 -351.567 -24.1406 0; 4 -477.808 -32.809 0;

5 -592.546 -40.6875 0; 6 -465.302 -204.411 0; 7 -430.863 -428.38 0;

8 -396.425 -652.35 0; 9 -361.986 -876.32 0; 10 -230.07 -1044.67 0;

11 -98.1537 -1213.02 0; 12 33.7623 -1381.37 0; 13 165.678 -1549.72 0;

14 219.79 -1556.37 0; 15 370.685 -1575 0; 16 628.444 -1579.29 0;

17 886.204 -1583.57 0; 18 1125.14 -1587.86 0; 19 1420.11 -1592.14 0;

20 1659.48 -1596.43 0; 21 1915.04 -1600.71 0; 22 2175 -1605 0;

23 2434.93 -1599 0; 24 2696.73 -1593 0; 25 2929.79 -1587 0; 26 3224.72 -1581 0;

27 3479.31 -1575 0; 28 3629.79 -1556.42 0; 29 3684.32 -1549.72 0;

30 3815.52 -1381 0; 31 3946.73 -1212.28 0; 32 4077.93 -1043.56 0;

33 4209.14 -874.835 0; 34 4252.52 -632.014 0; 35 4295.89 -389.192 0;

36 4100 -99.9998 0; 37 4322.29 -116.351 0; 38 4437.47 -124.823 0; 39 0 0 200;

40 -175.783 -12.0703 200; 41 -351.567 -24.1406 200; 42 -477.808 -32.809 200;

43 -592.546 -40.6875 200; 44 -465.302 -204.411 200; 45 -430.863 -428.38 200;

46 -396.425 -652.35 200; 47 -361.986 -876.32 200; 48 -230.07 -1044.67 200;

49 -98.1537 -1213.02 200; 50 33.7623 -1381.37 200; 51 165.678 -1549.72 200;

52 219.79 -1556.37 200; 53 370.685 -1575 200; 54 628.444 -1579.29 200;

55 886.204 -1583.57 200; 56 1125.14 -1587.86 200; 57 1420.11 -1592.14 200;

58 1659.48 -1596.43 200; 59 1915.04 -1600.71 200; 60 2175 -1605 200;

61 2434.93 -1599 200; 62 2696.73 -1593 200; 63 2929.79 -1587 200;

64 3224.72 -1581 200; 65 3479.31 -1575 200; 66 3629.79 -1556.42 200;

67 3684.32 -1549.72 200; 68 3815.52 -1381 200; 69 3946.73 -1212.28 200;

70 4077.93 -1043.56 200; 71 4209.14 -874.835 200; 72 4252.52 -632.014 200;

73 4295.89 -389.192 200; 74 4100 -99.9998 200; 75 4322.29 -116.351 200;

76 4437.47 -124.823 200; 77 0 0 400; 78 -175.783 -12.0703 400;

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82 -465.302 -204.411 400; 83 -430.863 -428.38 400; 84 -396.425 -652.35 400;

85 -361.986 -876.32 400; 86 -230.07 -1044.67 400; 87 -98.1537 -1213.02 400;

88 33.7623 -1381.37 400; 89 165.678 -1549.72 400; 90 219.79 -1556.37 400;

91 370.685 -1575 400; 92 628.444 -1579.29 400; 93 886.204 -1583.57 400;

94 1125.14 -1587.86 400; 95 1420.11 -1592.14 400; 96 1659.48 -1596.43 400;
97 1915.04 -1600.71 400; 98 2175 -1605 400; 99 2434.93 -1599 400;
100 2696.73 -1593 400; 101 2929.79 -1587 400; 102 3224.72 -1581 400;
103 3479.31 -1575 400; 104 3629.79 -1556.42 400; 105 3684.32 -1549.72 400;
106 3815.52 -1381 400; 107 3946.73 -1212.28 400; 108 4077.93 -1043.56 400;
109 4209.14 -874.835 400; 110 4252.52 -632.014 400; 111 4295.89 -389.192 400;
112 4100 -99.9998 400; 113 4322.29 -116.351 400; 114 4437.47 -124.823 400;
115 0 0 600; 116 -175.783 -12.0703 600; 117 -351.567 -24.1406 600;
118 -477.808 -32.809 600; 119 -592.546 -40.6875 600; 120 -465.302 -204.411 600;
121 -430.863 -428.38 600; 122 -396.425 -652.35 600; 123 -361.986 -876.32 600;
124 -230.07 -1044.67 600; 125 -98.1537 -1213.02 600; 126 33.7623 -1381.37 600;
127 165.678 -1549.72 600; 128 219.79 -1556.37 600; 129 370.685 -1575 600;
130 628.444 -1579.29 600; 131 886.204 -1583.57 600; 132 1125.14 -1587.86 600;
133 1420.11 -1592.14 600; 134 1659.48 -1596.43 600; 135 1915.04 -1600.71 600;
136 2175 -1605 600; 137 2434.93 -1599 600; 138 2696.73 -1593 600;
139 2929.79 -1587 600; 140 3224.72 -1581 600; 141 3479.31 -1575 600;
142 3629.79 -1556.42 600; 143 3684.32 -1549.72 600; 144 3815.52 -1381 600;
145 3946.73 -1212.28 600; 146 4077.93 -1043.56 600; 147 4209.14 -874.835 600;
148 4252.52 -632.014 600; 149 4295.89 -389.192 600; 150 4100 -99.9998 600;
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154 -175.783 -12.0703 800; 155 -351.567 -24.1406 800; 156 -477.808 -32.809 800;
157 -592.546 -40.6875 800; 158 -465.302 -204.411 800; 159 -430.863 -428.38 800;
160 -396.425 -652.35 800; 161 -361.986 -876.32 800; 162 -230.07 -1044.67 800;
163 -98.1537 -1213.02 800; 164 33.7623 -1381.37 800; 165 165.678 -1549.72 800;
166 219.79 -1556.37 800; 167 370.685 -1575 800; 168 628.444 -1579.29 800;
169 886.204 -1583.57 800; 170 1125.14 -1587.86 800; 171 1420.11 -1592.14 800;
172 1659.48 -1596.43 800; 173 1915.04 -1600.71 800; 174 2175 -1605 800;
175 2434.93 -1599 800; 176 2696.73 -1593 800; 177 2929.79 -1587 800;
178 3224.72 -1581 800; 179 3479.31 -1575 800; 180 3629.79 -1556.42 800;
181 3684.32 -1549.72 800; 182 3815.52 -1381 800; 183 3946.73 -1212.28 800;
184 4077.93 -1043.56 800; 185 4209.14 -874.835 800; 186 4252.52 -632.014 800;
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199 -361.986 -876.32 1000; 200 -230.07 -1044.67 1000;
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203 165.678 -1549.72 1000; 204 219.79 -1556.37 1000; 205 370.685 -1575 1000;
206 628.444 -1579.29 1000; 207 886.204 -1583.57 1000;
208 1125.14 -1587.86 1000; 209 1420.11 -1592.14 1000;
210 1659.48 -1596.43 1000; 211 1915.04 -1600.71 1000; 212 2175 -1605 1000;
213 2434.93 -1599 1000; 214 2696.73 -1593 1000; 215 2929.79 -1587 1000;
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219 3684.32 -1549.72 1000; 220 3815.52 -1381 1000; 221 3946.73 -1212.28 1000;
222 4077.93 -1043.56 1000; 223 4209.14 -874.835 1000;
224 4252.52 -632.014 1000; 225 4295.89 -389.192 1000; 226 4100 -99.9998 1000;
227 4322.29 -116.351 1000; 228 4437.47 -124.823 1000;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 4 6; 6 6 7; 7 7 8; 8 8 9; 9 9 10; 10 10 11;
11 11 12; 12 12 13; 13 13 14; 14 14 15; 15 15 16; 16 16 17; 17 17 18; 18 18 19;
19 19 20; 20 20 21; 21 21 22; 22 22 23; 23 23 24; 24 24 25; 25 25 26; 26 26 27;
27 27 28; 28 28 29; 29 29 30; 30 30 31; 31 31 32; 32 32 33; 33 33 34; 34 34 35;
35 35 37; 36 36 37; 37 37 38; 38 1 39; 39 2 40; 40 3 41; 41 4 42; 42 5 43;
43 6 44; 44 7 45; 45 8 46; 46 9 47; 47 10 48; 48 11 49; 49 12 50; 50 13 51;
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99 62 63; 100 63 64; 101 64 65; 102 65 66; 103 66 67; 104 67 68; 105 68 69;
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127 53 91; 128 54 92; 129 55 93; 130 56 94; 131 57 95; 132 58 96; 133 59 97;
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146 72 110; 147 73 111; 148 74 112; 149 75 113; 150 76 114; 151 77 78;
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185 111 113; 186 112 113; 187 113 114; 188 77 115; 189 78 116; 190 79 117;
191 80 118; 192 81 119; 193 82 120; 194 83 121; 195 84 122; 196 85 123;

197 86 124; 198 87 125; 199 88 126; 200 89 127; 201 90 128; 202 91 129;
203 92 130; 204 93 131; 205 94 132; 206 95 133; 207 96 134; 208 97 135;
209 98 136; 210 99 137; 211 100 138; 212 101 139; 213 102 140; 214 103 141;
215 104 142; 216 105 143; 217 106 144; 218 107 145; 219 108 146; 220 109 147;
221 110 148; 222 111 149; 223 112 150; 224 113 151; 225 114 152; 226 115 116;
227 116 117; 228 117 118; 229 118 119; 230 118 120; 231 120 121; 232 121 122;
233 122 123; 234 123 124; 235 124 125; 236 125 126; 237 126 127; 238 127 128;
239 128 129; 240 129 130; 241 130 131; 242 131 132; 243 132 133; 244 133 134;
245 134 135; 246 135 136; 247 136 137; 248 137 138; 249 138 139; 250 139 140;
251 140 141; 252 141 142; 253 142 143; 254 143 144; 255 144 145; 256 145 146;
257 146 147; 258 147 148; 259 148 149; 260 149 151; 261 150 151; 262 151 152;
263 115 153; 264 116 154; 265 117 155; 266 118 156; 267 119 157; 268 120 158;
269 121 159; 270 122 160; 271 123 161; 272 124 162; 273 125 163; 274 126 164;
275 127 165; 276 128 166; 277 129 167; 278 130 168; 279 131 169; 280 132 170;
281 133 171; 282 134 172; 283 135 173; 284 136 174; 285 137 175; 286 138 176;
287 139 177; 288 140 178; 289 141 179; 290 142 180; 291 143 181; 292 144 182;
293 145 183; 294 146 184; 295 147 185; 296 148 186; 297 149 187; 298 150 188;
299 151 189; 300 152 190; 301 153 154; 302 154 155; 303 155 156; 304 156 157;
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311 163 164; 312 164 165; 313 165 166; 314 166 167; 315 167 168; 316 168 169;
317 169 170; 318 170 171; 319 171 172; 320 172 173; 321 173 174; 322 174 175;
323 175 176; 324 176 177; 325 177 178; 326 178 179; 327 179 180; 328 180 181;
329 181 182; 330 182 183; 331 183 184; 332 184 185; 333 185 186; 334 186 187;
335 187 189; 336 188 189; 337 189 190; 338 153 191; 339 154 192; 340 155 193;
341 156 194; 342 157 195; 343 158 196; 344 159 197; 345 160 198; 346 161 199;
347 162 200; 348 163 201; 349 164 202; 350 165 203; 351 166 204; 352 167 205;
353 168 206; 354 169 207; 355 170 208; 356 171 209; 357 172 210; 358 173 211;
359 174 212; 360 175 213; 361 176 214; 362 177 215; 363 178 216; 364 179 217;
365 180 218; 366 181 219; 367 182 220; 368 183 221; 369 184 222; 370 185 223;
371 186 224; 372 187 225; 373 188 226; 374 189 227; 375 190 228; 376 191 192;
377 192 193; 378 193 194; 379 194 195; 380 194 196; 381 196 197; 382 197 198;
383 198 199; 384 199 200; 385 200 201; 386 201 202; 387 202 203; 388 203 204;
389 204 205; 390 205 206; 391 206 207; 392 207 208; 393 208 209; 394 209 210;
395 210 211; 396 211 212; 397 212 213; 398 213 214; 399 214 215; 400 215 216;
401 216 217; 402 217 218; 403 218 219; 404 219 220; 405 220 221; 406 221 222;
407 222 223; 408 223 224; 409 224 225; 410 225 227; 411 226 227; 412 227 228;
ELEMENT INCIDENCES SHELL
10001 1 39 40 2; 10002 2 40 41 3; 10003 3 41 42 4; 10004 4 42 43 5;

10005 4 42 44 6; 10006 6 44 45 7; 10007 7 45 46 8; 10008 8 46 47 9;
10009 9 47 48 10; 10010 10 48 49 11; 10011 11 49 50 12; 10012 12 50 51 13;
10013 14 52 51 13; 10014 15 53 52 14; 10015 16 54 53 15; 10016 17 55 54 16;
10017 18 56 55 17; 10018 19 57 56 18; 10019 20 58 57 19; 10020 21 59 58 20;
10021 22 60 59 21; 10022 23 61 60 22; 10023 24 62 61 23; 10024 25 63 62 24;
10025 26 64 63 25; 10026 27 65 64 26; 10027 28 66 65 27; 10028 29 67 66 28;
10029 30 68 67 29; 10030 31 69 68 30; 10031 32 70 69 31; 10032 33 71 70 32;
10033 34 72 71 33; 10034 35 73 72 34; 10035 37 75 73 35; 10036 37 75 74 36;
10037 38 76 75 37; 10338 39 77 78 40; 10339 40 78 79 41; 10340 41 79 80 42;
10341 42 80 81 43; 10342 42 80 82 44; 10343 44 82 83 45; 10344 45 83 84 46;
10345 46 84 85 47; 10346 47 85 86 48; 10347 48 86 87 49; 10348 49 87 88 50;
10349 50 88 89 51; 10350 52 90 89 51; 10351 53 91 90 52; 10352 54 92 91 53;
10353 55 93 92 54; 10354 56 94 93 55; 10355 57 95 94 56; 10356 58 96 95 57;
10357 59 97 96 58; 10358 60 98 97 59; 10359 61 99 98 60; 10360 62 100 99 61;
10361 63 101 100 62; 10362 64 102 101 63; 10363 65 103 102 64;
10364 66 104 103 65; 10365 67 105 104 66; 10366 68 106 105 67;
10367 69 107 106 68; 10368 70 108 107 69; 10369 71 109 108 70;
10370 72 110 109 71; 10371 73 111 110 72; 10372 75 113 111 73;
10373 75 113 112 74; 10374 76 114 113 75; 10375 77 115 116 78;
10376 78 116 117 79; 10377 79 117 118 80; 10378 80 118 119 81;
10379 80 118 120 82; 10380 82 120 121 83; 10381 83 121 122 84;
10382 84 122 123 85; 10383 85 123 124 86; 10384 86 124 125 87;
10385 87 125 126 88; 10386 88 126 127 89; 10387 90 128 127 89;
10388 91 129 128 90; 10389 92 130 129 91; 10390 93 131 130 92;
10391 94 132 131 93; 10392 95 133 132 94; 10393 96 134 133 95;
10394 97 135 134 96; 10395 98 136 135 97; 10396 99 137 136 98;
10397 100 138 137 99; 10398 101 139 138 100; 10399 102 140 139 101;
10400 103 141 140 102; 10401 104 142 141 103; 10402 105 143 142 104;
10403 106 144 143 105; 10404 107 145 144 106; 10405 108 146 145 107;
10406 109 147 146 108; 10407 110 148 147 109; 10408 111 149 148 110;
10409 113 151 149 111; 10410 113 151 150 112; 10411 114 152 151 113;
10412 115 153 154 116; 10413 116 154 155 117; 10414 117 155 156 118;
10415 118 156 157 119; 10416 118 156 158 120; 10417 120 158 159 121;
10418 121 159 160 122; 10419 122 160 161 123; 10420 123 161 162 124;
10421 124 162 163 125; 10422 125 163 164 126; 10423 126 164 165 127;
10424 128 166 165 127; 10425 129 167 166 128; 10426 130 168 167 129;
10427 131 169 168 130; 10428 132 170 169 131; 10429 133 171 170 132;
10430 134 172 171 133; 10431 135 173 172 134; 10432 136 174 173 135;

10433 137 175 174 136; 10434 138 176 175 137; 10435 139 177 176 138;
10436 140 178 177 139; 10437 141 179 178 140; 10438 142 180 179 141;
10439 143 181 180 142; 10440 144 182 181 143; 10441 145 183 182 144;
10442 146 184 183 145; 10443 147 185 184 146; 10444 148 186 185 147;
10445 149 187 186 148; 10446 151 189 187 149; 10447 151 189 188 150;
10448 152 190 189 151; 10449 153 191 192 154; 10450 154 192 193 155;
10451 155 193 194 156; 10452 156 194 195 157; 10453 156 194 196 158;
10454 158 196 197 159; 10455 159 197 198 160; 10456 160 198 199 161;
10457 161 199 200 162; 10458 162 200 201 163; 10459 163 201 202 164;
10460 164 202 203 165; 10461 166 204 203 165; 10462 167 205 204 166;
10463 168 206 205 167; 10464 169 207 206 168; 10465 170 208 207 169;
10466 171 209 208 170; 10467 172 210 209 171; 10468 173 211 210 172;
10469 174 212 211 173; 10470 175 213 212 174; 10471 176 214 213 175;
10472 177 215 214 176; 10473 178 216 215 177; 10474 179 217 216 178;
10475 180 218 217 179; 10476 181 219 218 180; 10477 182 220 219 181;
10478 183 221 220 182; 10479 184 222 221 183; 10480 185 223 222 184;
10481 186 224 223 185; 10482 187 225 224 186; 10483 189 227 225 187;
10484 189 227 226 188; 10485 190 228 227 189;
ELEMENT PROPERTY
10001 10338 10375 10412 10449 THICKNESS 250 250 286 286
10002 10339 10376 10413 10450 THICKNESS 286 286 322 322
10003 10340 10377 10414 10451 THICKNESS 322 322 345 345
10004 10341 10378 10415 10452 THICKNESS 345 345 365 365
10005 10342 10379 10416 10453 THICKNESS 230
10006 10343 10380 10417 10454 THICKNESS 230
10007 10344 10381 10418 10455 THICKNESS 230
10008 10345 10382 10419 10456 THICKNESS 230
10009 10346 10383 10420 10457 THICKNESS 230 230 275 275
10010 10347 10384 10421 10458 THICKNESS 275 275 335 335
10011 10348 10385 10422 10459 THICKNESS 335 335 386 386
10012 10349 10386 10423 10460 THICKNESS 386 386 450 450
10013 10350 10387 10424 10461 THICKNESS 450
10014 10351 10388 10425 10462 THICKNESS 300 300 450 450
10015 10352 10389 10426 10463 THICKNESS 291 291 300 300
10016 10353 10390 10427 10464 THICKNESS 283 283 291 291
10017 10354 10391 10428 10465 THICKNESS 274 274 283 283
10018 10355 10392 10429 10466 THICKNESS 266 266 274 274
10019 10356 10393 10430 10467 THICKNESS 257 257 266 266

```
10020 10357 10394 10431 10468 THICKNESS 249 249 257 257
10021 10358 10395 10432 10469 THICKNESS 240 240 249 249
10022 10359 10396 10433 10470 THICKNESS 252 252 240 240
10023 10360 10397 10434 10471 THICKNESS 264 264 252 252
10024 10361 10398 10435 10472 THICKNESS 276 276 264 264
10025 10362 10399 10436 10473 THICKNESS 288 288 276 276
10026 10363 10400 10437 10474 THICKNESS 300 300 288 288
10027 10364 10401 10438 10475 THICKNESS 450 450 300 300
10028 10365 10402 10439 10476 THICKNESS 450
10029 10366 10403 10440 10477 THICKNESS 386 386 450 450
10030 10367 10404 10441 10478 THICKNESS 335 335 386 386
10031 10368 10405 10442 10479 THICKNESS 281 281 335 335
10032 10369 10406 10443 10480 THICKNESS 230 230 281 281
10033 10370 10407 10444 10481 THICKNESS 230
10034 10371 10408 10445 10482 THICKNESS 230
10035 10372 10409 10446 10483 THICKNESS 230
10036 10373 10410 10447 10484 THICKNESS 516 516 450 450
10037 10374 10411 10448 10485 THICKNESS 530 530 516 516
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 3.7
POISSON 0.17
DENSITY 2.5e-009
ALPHA 1.17e-005
DAMP 0.05
TYPE CONCRETE
STRENGTH FCU 0.0055
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
1 TO 412 PRIS YD 5 ZD 5
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
14 204 PINNED
28 218 PINNED
LOAD 1 LOADTYPE None  TITLE LOAD CASE 1 : DEAD LOAD
SELFWEIGHT Y -1
LOAD 2 LOADTYPE None  TITLE LOAD CASE 2 : SIDL
```

```
*********Track Plinth + Rails**********
ELEMENT LOAD
10018 TO 10020 10023 TO 10025 10355 TO 10357 10360 TO 10362 10392 TO 10394 -
10397 TO 10399 10429 TO 10431 10434 TO 10436 10466 TO 10468 10471 TO 10472 -
10473 PR GY -1.11e-006
MEMBER LOAD
*********Railing******************
74 149 224 299 374 UNI GY -4e-005
*********Cable Tray******************
44 TO 48 119 TO 123 194 TO 198 269 TO 273 344 TO 348 UNI GY -8.2e-005
44 TO 48 119 TO 123 194 TO 198 269 TO 273 344 TO 348 UMOM GZ -0.17
LOAD 3 LOADTYPE None  TITLE LOAD CASE 3 : LIVE LOAD
MEMBER LOAD
56 131 206 281 356 UNI GY -0.005
62 137 212 287 362 UNI GY -0.00621
LOAD COMB 4 COMBINATION LOAD CASE 4 : SLS LOAD COMBINATION
1 1.0 2 1.2 3 1.1
LOAD COMB 5 COMBINATION LOAD CASE 5 : ULS LOAD COMBINATION
1 1.25 2 2.0 3 1.75
PERFORM ANALYSIS PRINT ALL
PRINT SUPPORT REACTION ALL
FINISH
```

10.2.3 3D Model of Whole Span

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STAAD SPACE DXF IMPORT OF FINAL.DXF
START JOB INFORMATION
ENGINEER DATE 21-Jun-16
END JOB INFORMATION
INPUT WIDTH 79
UNIT MMS MTON
JOINT COORDINATES
1 0 0 0; 2 -175.783 -12.0703 0; 3 -351.567 -24.1406 0; 4 -477.808 -32.809 0;
5 -592.546 -40.6875 0; 6 -465.302 -204.411 0; 7 -430.863 -428.38 0;
8 -396.425 -652.35 0; 9 -361.986 -876.32 0; 10 -230.07 -1044.67 0;
**************so on************
5122 3815.52 -1381 26950; 5123 3946.73 -1212.28 26950;
5124 4077.93 -1043.56 26950; 5125 4209.14 -874.835 26950;
5126 4252.52 -632.014 26950; 5127 4295.89 -389.192 26950;
5128 4100 -99.9998 26950; 5129 4322.29 -116.351 26950;
5130 4437.47 -124.823 26950;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 4 6; 6 6 7; 7 7 8; 8 8 9; 9 9 10; 10 10 11;
11 11 12; 12 12 13; 13 13 14; 14 14 15; 15 15 16; 16 16 17; 17 17 18; 18 18 19;
19 19 20; 20 20 21; 21 21 22; 22 22 23; 23 23 24; 24 24 25; 25 25 26; 26 26 27;
**************so on************
24945 5080 5118 5117 5079; 24946 5081 5119 5118 5080;
24947 5082 5120 5119 5081; 24948 5083 5121 5120 5082;
24949 5084 5122 5121 5083; 24950 5085 5123 5122 5084;
24951 5086 5124 5123 5085; 24952 5087 5125 5124 5086;
24953 5088 5126 5125 5087; 24954 5089 5127 5126 5088;
24955 5091 5129 5127 5089; 24956 5091 5129 5128 5090;
24957 5092 5130 5129 5091;
ELEMENT PROPERTY
20000 20037 20074 20111 20148 20185 20222 20259 20296 20333 20370 20407 20444 -
20481 20518 20555 20592 20629 20666 20703 20740 20777 20814 20851 20888 -
20925 20962 20999 21036 21073 21110 21147 21184 21221 21258 21295 21332 -
21369 21406 21443 21480 21517 21554 21591 21628 21665 21702 21739 21776 -
21813 21850 21887 21924 21961 21998 22035 22072 22109 22146 22183 22220 -
22257 22294 22331 22368 22405 22442 22479 22516 22553 22590 22627 22664 -
22701 22738 22775 22812 22849 22886 22923 22960 22997 23034 23071 23108 -
23145 23182 23219 23256 23293 23330 23367 23404 23441 23478 23515 23552 -
```

```
23589 23626 23663 23700 23737 23774 23811 23848 23885 23922 23959 23996 -
24033 24070 24107 24144 24181 24218 24255 24292 24329 24366 24403 24440 -
24477 24514 24551 24588 24625 24662 24699 24736 24773 24810 24847 24884 -
24921 THICKNESS 250 250 286 286
**************so on************
20036 20073 20110 20147 20184 20221 20258 20295 20332 20369 20406 20443 20480 -
20517 20554 20591 20628 20665 20702 20739 20776 20813 20850 20887 20924 -
20961 20998 21035 21072 21109 21146 21183 21220 21257 21294 21331 21368 -
21405 21442 21479 21516 21553 21590 21627 21664 21701 21738 21775 21812 -
21849 21886 21923 21960 21997 22034 22071 22108 22145 22182 22219 22256 -
22293 22330 22367 22404 22441 22478 22515 22552 22589 22626 22663 22700 -
22737 22774 22811 22848 22885 22922 22959 22996 23033 23070 23107 23144 -
23181 23218 23255 23292 23329 23366 23403 23440 23477 23514 23551 23588 -
23625 23662 23699 23736 23773 23810 23847 23884 23921 23958 23995 24032 -
24069 24106 24143 24180 24217 24254 24291 24328 24365 24402 24439 24476 -
24513 24550 24587 24624 24661 24698 24735 24772 24809 24846 24883 24920 -
24957 THICKNESS 530 530 516 516
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 3.7
POISSON 0.17
DENSITY 2.5e-009
ALPHA 1.17e-005
DAMP 0.05
TYPE CONCRETE
STRENGTH FCU 0.0055
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
1 TO 10087 PRIS YD 5 ZD 5
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
128 FIXED BUT FX MX MY MZ
142 FIXED BUT MX MY MZ
4992 FIXED BUT FX FZ MX MY MZ
5006 FIXED BUT FZ MX MY MZ
LOAD 1 LOADTYPE None  TITLE LOAD CASE 1 : DEAD LOAD
SELFWEIGHT Y -1
```

LOAD 2 LOADTYPE None TITLE LOAD CASE 2 : SIDL
********Track Plinth + Rails**********
ELEMENT LOAD
20017 TO 20019 20022 TO 20024 20054 TO 20056 20059 TO 20061 20091 TO 20093 -
20096 TO 20098 20128 TO 20130 20133 TO 20135 20165 TO 20167 20170 TO 20172 -
20202 TO 20204 20207 TO 20209 20239 TO 20241 20244 TO 20246 20276 TO 20278 -
20281 TO 20283 20313 TO 20315 20318 TO 20320 20350 TO 20352 20355 TO 20357 -
20387 TO 20389 20392 TO 20394 20424 TO 20426 20429 TO 20431 20461 TO 20463 -
20466 TO 20468 20498 TO 20500 20503 TO 20505 20535 TO 20537 20540 TO 20542 -
20572 TO 20574 20577 TO 20579 20609 TO 20611 20614 TO 20616 20646 TO 20648 -
20651 TO 20653 20683 TO 20685 20688 TO 20690 20720 TO 20722 20725 TO 20727 -
20757 TO 20759 20762 TO 20764 20794 TO 20796 20799 TO 20801 20831 TO 20833 -
20836 TO 20838 20868 TO 20870 20873 TO 20875 20905 TO 20907 20910 TO 20912 -
20942 TO 20944 20947 TO 20949 20979 TO 20981 20984 TO 20986 21016 TO 21018 -
21021 TO 21023 21053 TO 21055 21058 TO 21060 21090 TO 21092 21095 TO 21097 -
21127 TO 21129 21132 TO 21134 21164 TO 21166 21169 TO 21171 21201 TO 21203 -
21206 TO 21208 21238 TO 21240 21243 TO 21245 21275 TO 21277 21280 TO 21282 -
21312 TO 21314 21317 TO 21319 21349 TO 21351 21354 TO 21356 21386 TO 21388 -
21391 TO 21393 21423 TO 21425 21428 TO 21430 21460 TO 21462 21465 TO 21467 -
21497 TO 21499 21502 TO 21504 21534 TO 21536 21539 TO 21541 21571 TO 21573 -
21576 TO 21578 21608 TO 21610 21613 TO 21615 21645 TO 21647 21650 TO 21652 -
21682 TO 21684 21687 TO 21689 21719 TO 21721 21724 PR GY -1.11e-006
MEMBER LOAD
********Railing******************
74 149 224 299 374 449 524 599 674 749 824 899 974 1049 1124 1199 1274 1349 -
1424 1499 1574 1649 1724 1799 1874 1949 2024 2099 2174 2249 2324 2399 2474 -
2549 2624 2699 2774 2849 2924 2999 3074 3149 3224 3299 3374 3449 3524 3599 -
3674 3749 3824 3899 3974 4049 4124 4199 4274 4349 4424 4499 4574 4649 4724 -
4799 4874 4949 5024 5099 5174 5249 5324 5399 5474 5549 5624 5699 5774 5849 -
5924 5999 6074 6149 6224 6299 6374 6449 6524 6599 6674 6749 6824 6899 6974 -
7049 7124 7199 7274 7349 7424 7499 7574 7649 7724 7799 7874 7949 8024 8099 -
8174 8249 8324 8399 8474 8549 8624 8699 8774 8849 8924 8999 9074 9149 9224 -
9299 9374 9449 9524 9599 9674 9749 9824 9899 9974 10049 UNI GY -4e-005
********Railing******************
44 TO 48 119 TO 123 194 TO 198 269 TO 273 344 TO 348 419 TO 423 494 TO 498 -
569 TO 573 644 TO 648 719 TO 723 794 TO 798 869 TO 873 944 TO 948 -
1019 TO 1023 1094 TO 1098 1169 TO 1173 1244 TO 1248 1319 TO 1323 -
1394 TO 1398 1469 TO 1473 1544 TO 1548 1619 TO 1623 1694 TO 1698 -

1769 TO 1773 1844 TO 1848 1919 TO 1923 1994 TO 1998 2069 TO 2073 -
2144 TO 2148 2219 TO 2223 2294 TO 2298 2369 TO 2373 2444 TO 2448 -
2519 TO 2523 2594 TO 2598 2669 TO 2673 2744 TO 2748 2819 TO 2823 -
2894 TO 2898 2969 TO 2973 3044 TO 3048 3119 TO 3123 3194 TO 3198 -
3269 TO 3273 3344 TO 3348 3419 TO 3423 3494 TO 3498 3569 TO 3573 -
3644 TO 3648 3719 TO 3723 3794 TO 3798 3869 TO 3873 3944 TO 3948 -
4019 TO 4023 4094 TO 4098 4169 TO 4173 4244 TO 4248 4319 TO 4323 -
4394 TO 4398 4469 TO 4473 4544 TO 4548 4619 TO 4623 4694 TO 4698 -
4769 TO 4773 4844 TO 4848 4919 TO 4923 4994 TO 4998 5069 TO 5073 -
5144 TO 5148 5219 TO 5223 5294 TO 5298 5369 TO 5373 5444 TO 5448 -
5519 TO 5523 5594 TO 5598 5669 TO 5673 5744 TO 5748 5819 TO 5823 -
5894 TO 5898 5969 TO 5973 6044 TO 6048 6119 TO 6123 6194 TO 6198 -
6269 TO 6273 6344 TO 6348 6419 TO 6423 6494 TO 6498 6569 TO 6573 -
6644 TO 6648 6719 TO 6723 6794 TO 6798 6869 TO 6873 6944 TO 6948 -
7019 UNI GY -8.2e-005
7020 TO 7023 7094 TO 7098 7169 TO 7173 7244 TO 7248 7319 TO 7323 7394 TO 7398 -
7469 TO 7473 7544 TO 7548 7619 TO 7623 7694 TO 7698 7769 TO 7773 -
7844 TO 7848 7919 TO 7923 7994 TO 7998 8069 TO 8073 8144 TO 8148 -
8219 TO 8223 8294 TO 8298 8369 TO 8373 8444 TO 8448 8519 TO 8523 -
8594 TO 8598 8669 TO 8673 8744 TO 8748 8819 TO 8823 8894 TO 8898 -
8969 TO 8973 9044 TO 9048 9119 TO 9123 9194 TO 9198 9269 TO 9273 -
9344 TO 9348 9419 TO 9423 9494 TO 9498 9569 TO 9573 9644 TO 9648 -
9719 TO 9723 9794 TO 9798 9869 TO 9873 9944 TO 9948 10019 TO 10022 -
10023 UNI GY -8.2e-005
7020 TO 7023 7094 TO 7098 7169 TO 7173 7244 TO 7248 7319 TO 7323 7394 TO 7398 -
7469 TO 7473 7544 TO 7548 7619 TO 7623 7694 TO 7698 7769 TO 7773 -
7844 TO 7848 7919 TO 7923 7994 TO 7998 8069 TO 8073 8144 TO 8148 -
8219 TO 8223 8294 TO 8298 8369 TO 8373 8444 TO 8448 8519 TO 8523 -
8594 TO 8598 8669 TO 8673 8744 TO 8748 8819 TO 8823 8894 TO 8898 -
8969 TO 8973 9044 TO 9048 9119 TO 9123 9194 TO 9198 9269 TO 9273 -
9344 TO 9348 9419 TO 9423 9494 TO 9498 9569 TO 9573 9644 TO 9648 -
9719 TO 9723 9794 TO 9798 9869 TO 9873 9944 TO 9948 10019 TO 10022 -
10023 UNI GY -8.2e-005
ELEMENT LOAD
21725 21726 21756 TO 21758 21761 TO 21763 21793 TO 21795 21798 TO 21800 21830 -
21831 TO 21832 21835 TO 21837 21867 TO 21869 21872 TO 21874 21904 TO 21906 -
21909 TO 21911 21941 TO 21943 21946 TO 21948 21978 TO 21980 21983 TO 21985 -
22015 TO 22017 22020 TO 22022 22052 TO 22054 22057 TO 22059 22089 TO 22091 -

22094 TO 22096 22126 TO 22128 22131 TO 22133 22163 TO 22165 22168 TO 22170 -
22200 TO 22202 22205 TO 22207 22237 TO 22239 22242 TO 22244 22274 TO 22276 -
22279 TO 22281 22311 TO 22313 22316 TO 22318 22348 TO 22350 22353 TO 22355 -
22385 TO 22387 22390 TO 22392 22422 TO 22424 22427 TO 22429 22459 TO 22461 -
22464 TO 22466 22496 TO 22498 22501 TO 22503 22533 TO 22535 22538 TO 22540 -
22570 TO 22572 22575 TO 22577 22607 TO 22609 22612 TO 22614 22644 TO 22646 -
22649 TO 22651 22681 TO 22683 22686 TO 22688 22718 TO 22720 22723 TO 22725 -
22755 TO 22757 22760 TO 22762 22792 TO 22794 22797 TO 22799 22829 TO 22831 -
22834 TO 22836 22866 TO 22868 22871 TO 22873 22903 TO 22905 22908 TO 22910 -
22940 TO 22942 22945 TO 22947 22977 TO 22979 22982 TO 22984 23014 TO 23016 -
23019 TO 23021 23051 TO 23053 23056 TO 23058 23088 TO 23090 23093 TO 23095 -
23125 TO 23127 23130 TO 23132 23162 TO 23164 23167 TO 23169 23199 TO 23201 -
23204 TO 23206 23236 TO 23238 23241 TO 23243 23273 TO 23275 23278 TO 23280 -
23310 TO 23312 23315 TO 23317 23347 TO 23349 23352 TO 23354 23384 TO 23386 -
23389 TO 23391 23421 TO 23423 23426 TO 23428 23458 PR GY -1.11e-006
23459 23460 23463 TO 23465 23495 TO 23497 23500 TO 23502 23532 TO 23534 23537 -
23538 TO 23539 23569 TO 23571 23574 TO 23576 23606 TO 23608 23611 TO 23613 -
23643 TO 23645 23648 TO 23650 23680 TO 23682 23685 TO 23687 23717 TO 23719 -
23722 TO 23724 23754 TO 23756 23759 TO 23761 23791 TO 23793 23796 TO 23798 -
23828 TO 23830 23833 TO 23835 23865 TO 23867 23870 TO 23872 23902 TO 23904 -
23907 TO 23909 23939 TO 23941 23944 TO 23946 23976 TO 23978 23981 TO 23983 -
24013 TO 24015 24018 TO 24020 24050 TO 24052 24055 TO 24057 24087 TO 24089 -
24092 TO 24094 24124 TO 24126 24129 TO 24131 24161 TO 24163 24166 TO 24168 -
24198 TO 24200 24203 TO 24205 24235 TO 24237 24240 TO 24242 24272 TO 24274 -
24277 TO 24279 24309 TO 24311 24314 TO 24316 24346 TO 24348 24351 TO 24353 -
24383 TO 24385 24388 TO 24390 24420 TO 24422 24425 TO 24427 24457 TO 24459 -
24462 TO 24464 24494 TO 24496 24499 TO 24501 24531 TO 24533 24536 TO 24538 -
24568 TO 24570 24573 TO 24575 24605 TO 24607 24610 TO 24612 24642 TO 24644 -
24647 TO 24649 24679 TO 24681 24684 TO 24686 24716 TO 24718 24721 TO 24723 -
24753 TO 24755 24758 TO 24760 24790 TO 24792 24795 TO 24797 24827 TO 24829 -
24832 TO 24834 24864 TO 24866 24869 TO 24871 24901 TO 24903 24906 TO 24908 -
24938 TO 24940 24943 TO 24945 PR GY -1.11e-006
MEMBER LOAD
44 TO 48 119 TO 123 194 TO 198 269 TO 273 344 TO 348 419 TO 423 494 TO 498 -
569 TO 573 644 TO 648 719 TO 723 794 TO 798 869 TO 873 944 TO 948 -
1019 TO 1023 1094 TO 1098 1169 TO 1173 1244 TO 1248 1319 TO 1323 -
1394 TO 1398 1469 TO 1473 1544 TO 1548 1619 TO 1623 1694 TO 1698 -
1769 TO 1773 1844 TO 1848 1919 TO 1923 1994 TO 1998 2069 TO 2073 -

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2144 TO 2148 2219 TO 2223 2294 TO 2298 2369 TO 2373 2444 TO 2448 -
2519 TO 2523 2594 TO 2598 2669 TO 2673 2744 TO 2748 2819 TO 2823 -
2894 TO 2898 2969 TO 2973 3044 TO 3048 3119 TO 3123 3194 TO 3198 -
3269 TO 3273 3344 TO 3348 3419 TO 3423 3494 TO 3498 3569 TO 3573 -
3644 TO 3648 3719 TO 3723 3794 TO 3798 3869 TO 3873 3944 TO 3948 -
4019 TO 4023 4094 TO 4098 4169 TO 4173 4244 TO 4248 4319 TO 4323 -
4394 TO 4398 4469 TO 4473 4544 TO 4548 4619 TO 4623 4694 TO 4698 -
4769 TO 4773 4844 TO 4848 4919 TO 4923 4994 TO 4998 5069 TO 5073 -
5144 TO 5148 5219 TO 5223 5294 TO 5298 5369 TO 5373 5444 TO 5448 -
5519 TO 5523 5594 TO 5598 5669 TO 5673 5744 TO 5748 5819 TO 5823 -
5894 TO 5898 5969 TO 5973 6044 TO 6048 6119 TO 6123 6194 TO 6198 -
6269 TO 6273 6344 TO 6348 6419 TO 6423 6494 TO 6498 6569 TO 6573 -
6644 TO 6648 6719 TO 6723 6794 TO 6798 6869 TO 6873 6944 TO 6948 -
7019  UMOM GZ -0.17
7020 TO 7023 7094 TO 7098 7169 TO 7173 7244 TO 7248 7319 TO 7323 7394 TO 7398 -
7469 TO 7473 7544 TO 7548 7619 TO 7623 7694 TO 7698 7769 TO 7773 -
7844 TO 7848 7919 TO 7923 7994 TO 7998 8069 TO 8073 8144 TO 8148 -
8219 TO 8223 8294 TO 8298 8369 TO 8373 8444 TO 8448 8519 TO 8523 -
8594 TO 8598 8669 TO 8673 8744 TO 8748 8819 TO 8823 8894 TO 8898 -
8969 TO 8973 9044 TO 9048 9119 TO 9123 9194 TO 9198 9269 TO 9273 -
9344 TO 9348 9419 TO 9423 9494 TO 9498 9569 TO 9573 9644 TO 9648 -
9719 TO 9723 9794 TO 9798 9869 TO 9873 9944 TO 9948 10019 TO 10022 -
10023 UMOM GZ -0.17
LOAD 3 LOADTYPE None  TITLE LOAD CASE 3 : LIVE LOAD AT SUPPORT
JOINT LOAD
133 139 1463 1469 4807 4813 FY -13.36
MEMBER LOAD
1181 1187 3806 3812 8531 8537 CON GY -13.36
LOAD 4 LOADTYPE None  TITLE LOAD CASE 4 : LIVE LOAD AT MID SPAN
JOINT LOAD
893 899 4237 4243 FY -13.36
MEMBER LOAD
2681 2687 7406 7412 CON GY -13.36
LOAD COMB 5 COMBINATION LOAD CASE 5 : SLS LOAD COMBINATION (AT SUPPORT)
1 1.0 2 1.2 3 1.0
LOAD COMB 6 COMBINATION LOAD CASE 6 : ULS LOAD COMBINATION (AT SUPPORT)
1 1.25 2 2.0 3 1.75
LOAD COMB 7 COMBINATION LOAD CASE 7 : SLS LOAD COMBINATION (AT MID SPAN)
```

1 1.0 2 1.2 4 1.0

LOAD COMB 8 COMBINATION LOAD CASE 8 : ULS LOAD COMBINATION (AT MID SPAN)

1 1.25 2 2.0 4 1.75

PERFORM ANALYSIS

PRINT SUPPORT REACTION ALL

FINISH