Analysis and Design of Pedestrian Bridge using Pultruded Composites

By

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14MCLC26

DEPARTMENT OF CIVIL ENGINEERING

INSTITUTE OF TECHNOLOGY

NIRMA UNIVERSITY

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Analysis and Design of Pedestrian Bridge using Pultruded Composites

Submitted in Partial Fulfillment of the Requirements for the Degree of

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IN

CIVIL ENGINEERING

(Computer Aided Structural Analysis And Design)

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Declaration

This is to certify that

a. The thesis comprises my original work towards the Degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) at Nirma University and has not been submitted elsewhere for a degree.
b. Due acknowledgment has been made in the text to all other material used.

Devansh S. Shah

Certificate

This is to certify that the Major Project entitled **Analysis and Design of Pedestrian Bridge using Pultruded Composites"** submitted by **Mr. Devansh S. Shah (14MCLC26)**, towards the partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) of Nirma University, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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Abstract

Over the many years, the materials which were utilized as a part of the development of pedestrian bridge are wood, steel and concrete. The impact of environment on these materials has all in all, a huge effect on expense of the structure because of its maintenance and rehabilitation. The need of faster and lighter and less maintenance structure has lead to the advancement of the new basic materials. The new materials are known as composites. These materials were initially utilized in 1950s. A groundbreaking part of the composites that are utilized by present day society is the Plastic Reinforced with different sorts of filaments, likewise named by fiber strengthened polymer(FRP). The application field of FRP was confined to aviation and marine commercial enterprises. However in the most recent couple of years, the need of the construction industry, the advances in the research in construction field and also the reduction in cost of FRP generation, assent the use of composites as a part of construction industry. These composites materials have been used as a part of number of structures to-date, for example, pedestrian bridges, cooling tower and walkways, etc. Due to many advantages of composites, they have been used in several ways in construction of bridges.

In the present study the analysis and design of a pedestrian bridge using pultruded composites is studied under static load cases. Two different profiles of the pedestrian bridge are considered Beam Type and Truss Type Pedestrian Bridge. Five different spans are considered for the analysis and design. The different spans are 3m, 5m, 10m, 15m and 20m. The analysis is done using staad pro software. The design of the pedestrian bridge is done using Fiberline Design Manual and National Research Council of Italy.

The parametric study is carried out for the Beam Type and Truss Type Pedestrian Bridge. The pultruded sections are compared with each other to determine the most optimum section for the particular type of pedestrian bridge. The pultruded composites are compared with steel sections to determine the difference in the load carrying capacity of both the materials. In beam type pedestrian bridge the moment capacity is kept constant and different parameters like shear capacity, deflection and weight are compared for different sections. Similarly for truss type pedestrian bridge the axial load carrying capacity is kept constant and weight is compared for different sections.

From the study it is found that for the beam type of pedestrian bridge by keeping moment constant the shear capacity of steel sections are higher than the pultruded sections. Similarly the deflections of steel sections are lower than the pultruded sections, while the weight of the pultruded sections are lesser than the steel sections. similarly for truss type pedestrian bridge by keeping axial load constant it is observed that the weight of pultruded sections are lower than the steel sections.

The cost estimation is also carried out for the pultruded composites and steel. The cost estimation is carried out for the superstructure only. The cost considered is only the material cost, and transportation cost and labour cost are not considered. From the study it is found that the cost of pultruded composites are lower than the steel sections. The total cost of superstructure of pultruded sections are lower than the steel sections.

Abbreviation, Notation and Nomenclature

A .... Cross Sectional area

A_v .... Area of cross section resistant to shear

E .... Modulus of Elasticity

G .... Shear Modulus of Elasticity

J,I .... Moment of Inertia

L .... Length between two consecutive flexural-torsional restraint

L_o .... Buckling Length

M_{max} .... Maximum bending moment value

$M_{loc,Rd}$ .... Design value of bending moment

M_{Rd1} .... Design value of resisting moment

M_{Rd2} .... Design value if bending moment which provokes the instability of element

$N_{c,Rd1}$ .... Design value of compressive strength

$N_{c,Rd2}$ ... Design value of the normal force which provokes the instability of the element

N_{Eul} .... Eulerian Critical Load

$N_{loc,Rd}$ ... Design value of the normal force which provokes the instability of the element

$N_{t,Rd}$ .... Design value of Axial resistance

$N_{t,Sd}$ .... Design value of axial load

W .... Section Modulus

N_d .... Design value of the compressive load

f_c .... Compresive Strength

γmf .... Partial Coefficients

N_{cr} .... Critical load on Column

F_d .... Compressive load

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Chapter 1

Introduction

1.1 General

Over the few years, the materials which were used in the construction of pedestrian bridges were wood, steel and reinforced concrete. The effect of environment on these materials has in general, a significant impact on cost of the structure due to its maintenance and rehabilitation. In addition, the need of faster and lighter and less maintenance structure has lead to the development of the new structural materials. The new materials are known as composites. These materials were first used in 1950s. A momentous part of the composites that are used by modern society is the Plastic Reinforced with various types of fibers, also named by fiber reinforced polymer (FRP). The application field of FRP was restricted to aerospace and marine industries. However in the last few years, the need of the construction industry, the advances in the research in composites field and in addition the decrease in cost of FRP production, acquiesce the used of composites in construction industry. These structural materials have been used in number of structures to-date such as pedestrian bridges, cooling tower and walkways. Due to many advantages of composites, they have been used in several ways in construction of bridges.

There are many type of FRP composites are available like Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP). In fact GFRP composite materials have been used in bridges for over a decade. It is believed that the first GFRP composite pedestrian bridge was built by the Israelis in 1975 after which Europe, the U.S and Asia came into the industry. After the GFRP and CFRP the new material came into existence called Pultruded Fiber Reinforced Polymer called PFRP.The process of production of PFRP is called Pultrusion.Pultrusion process is used to produced pulturded profiles. Pultruded profiles are manufactured from a wide variety of high performance thermosetting resins and reinforcements. The pultruded profiles have been extensively used in many industries like construction, transportation, waste water applications etc. The pultrusion process is shown in the figure 1.1.

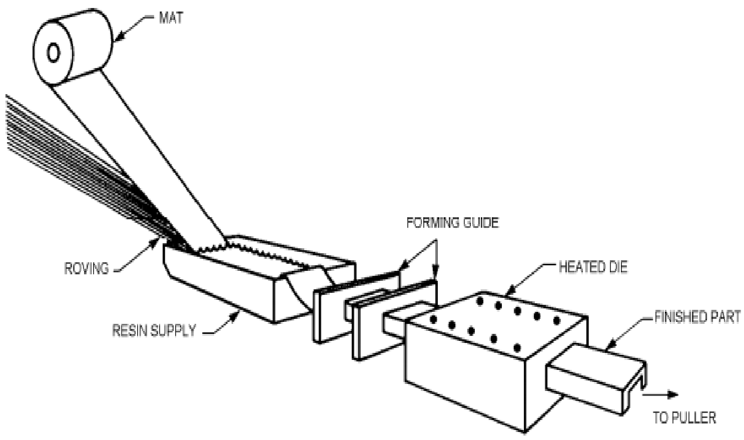


Figure 1.1: Pultrusion Process

Pultrusion is a continuous molding process using fiber reinforcement in polyester or other thermosetting resin matrices. Pre-selected reinforcement materials, such as fiberglass roving, mat or cloth, are drawn through a resin bath in which all materials is thoroughly impregnated with a liquid thermosetting resin. The wet-out fiber is formed to the desired geometric shape and pulled into a heated steel die. Once inside the die, the resin cure is initiated by controlling precise elevated temperatures. The laminate solidifies in the exact cavity shape of the die, as it is continuously pulled by the pultrusion machine. The shapes of the cavities can be any shape, some of the shapes are I, C, Angle, Box etc. Some of the major example of the pultrusion materials used in the bridges are shown figures below:

40 m long Fiberline bridge in Denmark

Figure 1.2: Fiberline Bridge, Denmark

38 m Llieda Footbridge, Spain

Figure 1.3: Llieda Footbridge, Spain

60 m long opening Fredrikstad bridge, Norway

Figure 1.4: Fredriskad Bridge, Norway

12.5 m Bridge in Switzerland

Figure 1.5: Bridge, Switzerland

1.2 Applications of the Pultruded Composites

Pultruded composites have used in many industries like Construction, Electrical, Waste water, marine, Automobile etc. Some of the applications are shown below:

- Construction/Industrial

  1. Bridges
  2. Cable trays
  3. Building Systems
  4. Cooling Towers
  5. Grating and Supports
  6. Prefabricated Walkways, Platforms and handrail systems
  7. Trusses and joists
  8. Wind Blades

- Automotive

  1. Automobile Springs
  2. Bus Components

3. Spring Bumpers
4. Tank Supports
5. Truck/trailer wall posts

- Marine

1. Boat dock power posts
2. Fender pilings
3. Sheetpiles

1.3 Need of Study

The use of steel components in construction of bridges is going on from last many decades. The weathering or environmental effects on the steel components leads to the corrosion of components. Corrosion of steel components leads to the higher cost of maintenance and it finally leads to the higher cost of the structure. The corrosion of the steel components may lead to the collapse of the structure. The self weight of the steel components is also high and these leads to the higher weight of the overall structure.

To overcome all these above disadvantages of the steel components the pultruded composites came into existence. The pultruded composites have negligence effects of the environment which reduced the corrosion effect. Due to less corrosion the cost of maintenance of the pultruded components is less which leads to the lesser cost of the structure than the steel structures. The weight of the pultruded composites are less than the steel structures and because of these the overall weight of the structure is less than the steel structures.

1.4 Objective of Study

Following objectives are studied in this major project:

- To study the behaviour of a Pedestrian Bridge using Pultruded Composites under static load cases.

- To study in detail beam type and truss type pedestrian bridge using pultruded composites.
- To perform parametric study of pultruded composites for beam type and truss type pedestrian bridge.
- To compare pultruded composites and steel for beam type and truss type pedestrian bridge.

1.5 Scope of Work

- Analysis and design of a pedestrian bridge using pultruded composites under static load cases
- Analysis and design of Beam type pedestrian bridge using pultruded composites.
- Analysis and design of truss type pedestrian bridge using pultruded composites.
- Compare pultruded composites for beam type pedestrian bridge with respect to moment capacity, shear capacity, deflection, weight and cost.
- Compare pultruded composites for truss type pedestrian bridge with respect to axial load capacity, weight and cost.
- Compare pultruded composites and steel with respect to moment capacity, shear capacity, deflection, weight and cost for beam type pedestrian bridge. In truss type pedestrian bridge the comparison is to be done with respect to axial force, weight and cost.
- The flowchart for the parametric study is shown in figure 1.6

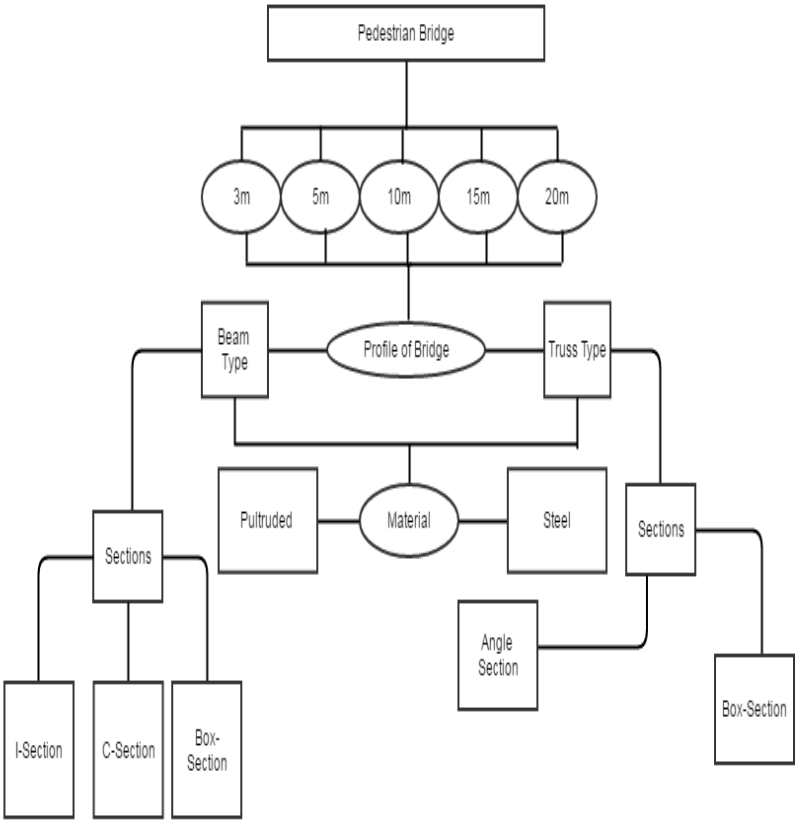


Figure 1.6: Flow chart for parametric study

1.6 Organization of Major Project

The content of report is divided into seven chapters as follows:

Chapter 1 gives general information about pedestrian bridge and introduction about the pultruded material, objective and scope of work.

Chapter 2 discusses the literature review. In this chapter literature regarding behaviour of pulturded beams and columns are discussed. The case study for the pedestrian bridge using pultruded composites is also discussed in this chapter.

Chapter 3 presents the design methodology for the design of pedestrian bridge using pultruded composites. It includes step by step procedure of design of various members for pedestrian bridge using Fiberline Design manual and National Council of Italy.

Chapter 4 shows the analysis and design of beam type and truss type pedestrian bridges for various spans using Fiberline Design Manual and National Council of Italy.

Chapter 5 shows the parametric study for beam type and truss type pedestrian bridge with respect to various parameters.

Chapter 6 shows the comparison of the cost for the beam type and truss type pedestrian bridge using pulturded composites with respect to steel sections.

Chapter 7 summarizes the work carried out in major project. It consists summary of various conclusions obtained from study and future scope of work.

Chapter 2

Literature Review

2.1 General

This chapter includes the literature study for the behavious of pultured beams and columns. It also shows the case study for the pedestrian bridge using pulturded composites. Various journal papers and guidelines are studied to understand the behaviour of pulturded material.

2.2 Behavior of Pultruded Beams

Nagaraj and Gangarao[1] studied the behavioir of the FRP pultruded beams under static load cases to emphasis on factors such as shear influence, warping, shear lag and failure modes. To achieve two different shapes i.e. box and wide flanges were tested. The sections used for box were: 102×102×6 mm and for wide flange: 152×152×6 sections made of vinyl ester matrix reinforced with E-glass fibers. The sections used for the testing are shown in Figure 2.1.

Materials testing systems (MTS) hydraulic system with a computer-monitored control panel was used to conduct the testing on beams with a span length of 1828 mm. The boundary conditions applied were simply supported and the testing was done under three point and four-point bending. In three point bending the load was applied at the center.Dial gauges or linear variable differential transducers (LVDTs), and electrical resistance strain gauges were used to measure deflections and strains, respectively. Strain

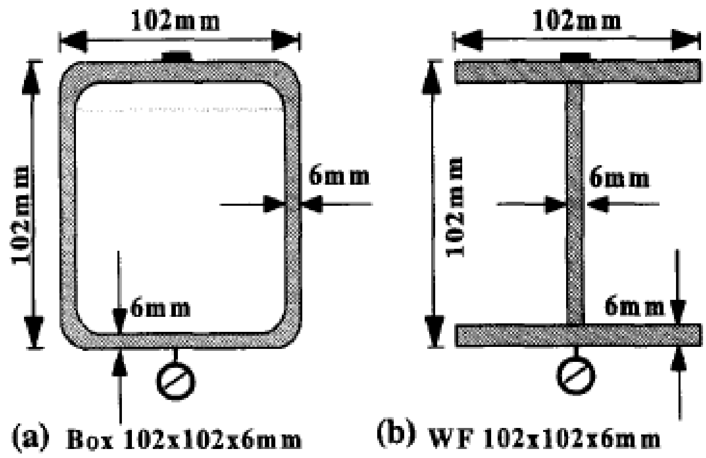


Figure 2.1: GFRP sections

gauges were mounted both on the tension and compression faces of the beam, equidistant from its midspan.

The results obtained showed that the shear influence on deflection mesurements was significant for both three-point and four-point bending load conditions. Shear lag effect was insignificant and warping was noticeable. Finite element analysis using ANSYSY software was also done by the authors to support the experimental results.

2.3 Behavior of Pultruded Column

G. Boscato et al.[3] studied the experimental and numerical investigation on the performance of build-up columns made by four FRP pultruded channel shapes connected through steel bolts along the length. The Figure 2.2 shows the different configuration for the buildup columns connected through steel bolts.

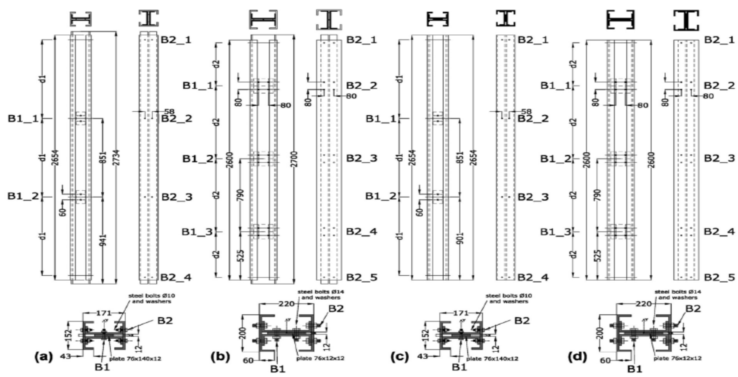


Figure 2.2: Different configurations for Build-up column

The Figure 2.3 shows the mechanical properties of the FRP material. The Figure 2.4 shows the geometric properties of the build-up columns resp.

Mechanical characteristics of pultruded FRP material. Mean values [25].

Mechanical properties	Symbol	Value
Longitudinal tensile strength	σ_Z	350 MPa
Transversal tensile strength	$\sigma_X = \sigma_Y$	70 MPa
Longitudinal elastic modulus	$E_Z = E_L$	23 GPa
Transversal elastic modulus	$E_X = E_Y = E_T$	8.5 GPa
Shear modulus	$G_{XY} = G_T$	3.4 GPa
Shear modulus	$G_{ZX} = G_{ZY} = G_{LT}$	3 GPa
Poisson's ratio	$\nu_{ZX} = \nu_{ZY} = \nu_{LT}$	0.23
Poisson's ratio	$\nu_{XY} = \nu_T$	0.09
Density	γ	1750 kg/m^3
Fibres percentage	V_f	40% in Volume

Figure 2.3: Mechanical properties of the FRP columns

Geometrical properties of built-up 4-channels members.

Property	Notation	Column 152	Column 200
Cross-sectional area of column	A	83.2 cm^2	120 cm^2
Minor-axis second moment of area	I_x	1369 cm^4	3569 cm^4
Major-axis second moment of area	I_y	3547 cm^4	8720 cm^4
Minor-axis shear area	$A_{s,x}$	37.1 cm^2	52.3 cm^2
Major-axis shear area	$A_{s,y}$	47.7 cm^2	67.9 cm^2
Torsional constant	I_T	166 cm^4	283 cm^4

Figure 2.4: Geometric Properties of the Build-up columns

Two columns with a different built-up cross-section have been tested in both configurations BC1 and BC2: column 200 is realized with four 200×60×10 mm C-profiles; the web of column 152 is made by two 152×43×6.5 mm C-profiles, one flange of the column is made by a 146 ×40×6.5 mm C-profile, and the other flange is made by a 152×43×9.5 mm C-profile.

Three specimens of column 152 with configuration BC1 (length 2734 mm) and one specimen of the remaining columns column 200 with configuration BC1 (length 2700 mm) and one column with configuration BC2 both for the type 152 (length 2654 mm) and 200 (length 2600 mm) were tested.The bolted connections have been designed with a distance up to 850 mm between the bolt rows to reduce the effective length of the individual C-profiles and the buckling phenomena. The test setup is shown in Figure 2.5.

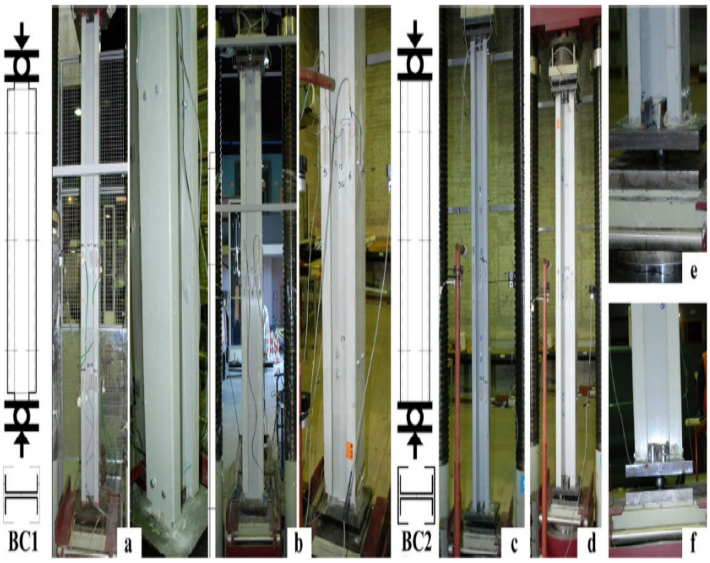


Figure 2.5: Test setup for build-up columns

All tests were performed by means of a 6000 kN maximum load press with data control system; the loading velocity was taken as 0.05 mm/s with displacement control procedure. The global response was measured by monitoring the lateral displacement along the Minor-axis (y direction) and Major-axis (x direction).
Linear displacement transducers with a stroke up to 100 mm, located at mid-height, were used. The results showed that the column 200 has higher ultimate load than the column 152. The moment torque loss is more in column 152 than column 200. For buckling load larger value was obtained for build-up column with bigger channels. The column 152 shows both the local and global buckling and local failure while the column 200 shows only the crushing at the ends of the profiles. Collapse and damage of column 152 is shown in Figure 2.6.

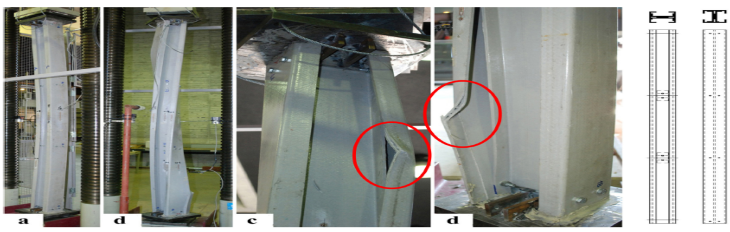


Figure 2.6: Collapse damage of column 152

The Figure 2.7 shows the collapse and damage of the column 200.

Figure 2.7: Collapse damage of column 200

2.4 Pedestrian Bridges

Yeou-Fong Li et al.[9] did the case study on the pedestrian bridge in Taiwan using pultruded composites. The main objective of the authors for such type of bridge was to showcase the superiority of lightweight, high-strength and environmental-resistant GFRP composites in civil engineering applications. The pedestrian bridge was made of four continuous GFRP I-girders and GFRP decks in its superstructure.

All the components of the bridge including the handrails, pins and components of the connections were also made of GFRP composites. The design of the bridge was done using AASHTOs Guide Specification for Design of FRP Pedestrian Bridge for the deflection criteria. The design parameters for the pedestrian bridge are shown below:

- Total Length: 8 m
- Span length: 7.5 m
- Width: 1.5 m
- Total Weight (Superstructure only): 1.2 tons

- Materials: Pultruded GFRP composites
- Maximum Deflections $\leq \frac{L}{500}$
- Load Capacity: 5 kN/m^2

Schematic diagram of the pedestrian bridge is shown in Figure 2.8.

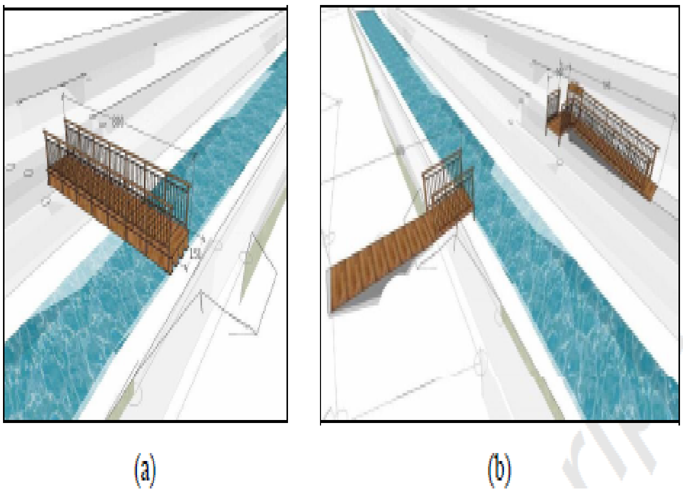


Figure 2.8: Schematic Diagram of the Pedestrian Bridge

The sections used for the girders are shown in Figure 2.9.

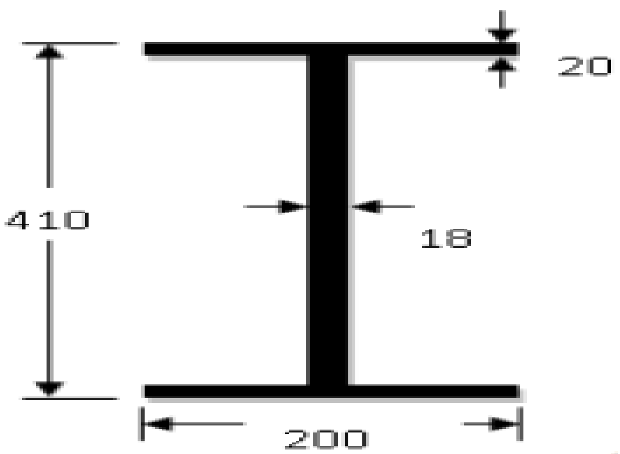


Figure 2.9: Setion Used for Girders

In this case study the detailed installation process including the architectural characteristics, the structural design is explained by the authors. The FEM analysis of the pedestrian bridge was done and the results are compared with the analytical results. All components of the bridge used non-steel materials to avoid any possibility of chloride action on the pedestrian bridge. Both structural members and nonstructural members were connected to one another using environmentally resistant GFRP pins(diameter = 6 mm) in conjunction with high strength epoxy resin adhesive.

Site investigation and surveying was first carried out. From that, the shape, color and design of the pedestrian bridge were decided. A computer-aided drawing of the pedestrian bridge was made to give a more realistic view. Construction began after the different sections of the pultruded GFRP members were delivered to the site from a factory approximately 160 km away. After the members arrived on site, their numbers were confirmed and a visual check was done to assure the members were not damaged during transportation.

2.5 Summary

All these papers gives an idea about the various research works carried out on this topic. These research papers gives idea about the behavior of the pultruded beams and columns. The case study gives idea about the pedestrian bridge constructed using pultruded composites and various parameters associated with it.

Chapter 3

Guidelines for Pedestrian Bridge

3.1 General

In this chapter the guidelines for the design of a pultruded composites are explained. As of now there is no code available for the design of pultruded composites. Few guidelines proposed by the manufacturer are available. Two guidelines are studied in this major project, Fiberline Design Manual and National Research Council of Italy. Both this guideliens are based on Ultimate Limit state methodology.

- **Ultimate Limit State**

Security against failure due to overload or lacking stability is assessed by partial coefficients being assigned to loads and strengths, respectively.

- **Serviceability Limit State**

Serviceability Limit State defines the performance criteria for serviceability and corresponds to conditions beyond which which specifies requirements resulting from the planned used use are no longer met. A structure that fails serviceability has exceeded the following limits:
Excessive Deflection
Vibration
Local Deflection

3.2 Guidelines for Design of Pedestrian Bridge

There is as of now no code is available for the design of a pultruded composites. Few guidelines are available for the design of a pultruded composites. The design of a pedestrian bridge is done by two guidelines they are, i) Fiberline design manual and ii) National Research Council of Italy.

3.2.1 Fiberline Design Manual

Fiberline Design Manual is the guideline proposed by the manufacturing plant Fiberline Industries inc. The fiberline manual is based on the Ultimate Limit State method. For the deflection criteria the Serviceability limit state methodology is adopted. Fiberline Design guidelines gives the deflection criteria between $\frac{L}{400}$ to $\frac{L}{200}$. The factor of safety was considered 1.5 as per the guideline. The design procedure of various members are shown below:

Design steps for the Girder

For Ultimate Limit state

g = Dead Load

q1 = Live load

Step-1: Calculation of UDL on Girder

$$P_d = \gamma_{mf} \times (g + q1) \tag{3.1}$$

where, γ_{mf} = Load Factor i.e 1.5

Step-2: Calculation of Moment

$$M = K_m P_d L^2 \tag{3.2}$$

where, K_m =0.125

Step-3: Calculation of Bending Stress

$$\sigma_{max} = \frac{M}{Wxx} \tag{3.3}$$

where, W_{xx} is Section Modulus

Step-4: Permissible Bending Stress

$$\sigma_{max} \leq f_b \tag{3.4}$$

Step-5: Shear Force Calculation

$$V_d = K_v P_d L \tag{3.5}$$

Where, $K_v = 0.625$

Step-6: Calculation of Shear Stress

$$\tau_{max} = \frac{V_d}{A_k} \tag{3.6}$$

Step-7: Permissible Shear Stress

$$\tau_{max} \leq f\tau \tag{3.7}$$

Step-8: Deflection

$$q_k = \frac{K\delta_m q_k L^3}{EIxx} + \frac{K\delta_v q_k L}{GA_k} \tag{3.8}$$

Step-9: Deflection Limit

$$q_k \leq \frac{L}{400} to \frac{L}{200} \tag{3.9}$$

The above procedure shows the design of the flexure members. The design procedure for the column/compression members are shown below:

Design steps for the Column/Compression member

For the column the design value N_d or the axial load should be lower than the critical load N_{cr}.

Step-1: Design Value

$$N_d \leq N_{cr} \tag{3.10}$$

Step-2: Critical Column Load

$$N_{cr} = \frac{F_d}{1 + \lambda_r^2} \tag{3.11}$$

Step-3: Slenderness Ratio

$$\lambda_r = \sqrt{\frac{f_c}{\sigma_{el}\gamma_{mf}}} \tag{3.12}$$

Step-4: Compressive Load

$$F_d = \frac{Af_c}{\gamma_{mf}} \tag{3.13}$$

Step-5: Euler Load

$$N_{el} = \frac{\pi^2 EI}{\gamma_m L_k^2} \tag{3.14}$$

Step-6: Stress Calculation

$$\sigma_{el} = \frac{N_{el}}{A} \tag{3.15}$$

Provided the $N_d \leq N_{cr}$ is met, the member is safe in compression.

The design procedure for the tension member is shown below:

Design steps for tension member

$$N_d \leq \frac{A.f_t}{\gamma_m} \tag{3.16}$$

3.2.2 National Research Council of Italy

National Council of Italy is based on the ultimate limit state methodology. For the deflection criteria the serviceability limit state methodology is adopted. National Research council of Italy gives the deflection criteria between $\frac{L}{300}$.

The factor of safety is 1.5 as per the guideline. The design steps for various members are shown below:

Design steps for Flexure Member

The structure subjected to in-plane flexure the design value of the bending moment, M_{sd}, should satisfy the limitation:
Step-1: Bending Moment

$$M_{sd} \leq M_{Rd1} \tag{3.17}$$

Step-2: The design value of the flexural resistance

$$M_{Rd1} = min(W.f_{t,d}, W.f_{c,d}) \tag{3.18}$$

where, W is the section modulus
Step-3: Design for shear

$$(V_{sd}) \leq (V_{Rd}) \tag{3.19}$$

Step-4: Design for Shear resistance

$$(V_{Rd}) = min(V_{Rd1}, V_{Rd2}) \tag{3.20}$$

$$V_{Rd1} = A_v.(f_{v,Rd1}) \tag{3.21}$$

where, (A_v) is the area resistant to shear and $(f_{v,Rd1})$ is the design shear resistant of the material.

$$V_{Rd2} = \frac{A_v.f_{v,loc,k})}{\gamma_f} \tag{3.22}$$

Step-5: Critical Stress Calculation

$$(f_{v,loc,k}) = \frac{4.(8.125 + 5.045.K)(D_{11}wD_{22}w^3)^{1/4}}{t_w.b_w^2} forK \leq 1 \tag{3.23}$$

$$(f_{v,loc,k}) = \frac{4.(11.71 + \frac{1.46}{K^2})\sqrt{(D_{22}w[(D_{12}w + 2.(D_{66}w)]}}{t_w b_w^2} for K \geq 1 \tag{3.24}$$

K assumes the form:

$$K = \frac{\frac{G_{LT}}{6} + \nu_{LT}\frac{E_{TC}}{12.(1-\nu_{LT}.\nu_{TL})}}{\sqrt{\frac{E_{LC}.E_{Tc}}{[12.(1-\nu_{Lt}\nu_{TL})]^2}}} \tag{3.25}$$

The design steps for the column/compression member is shown below:

Design steps for columns/compression members

In the case of elements subjected to axial compressive load, the design design value of the compressive force ($N_{c,sd}$) should satisfy the limitation:
Step-1: Design value of Compressive Force

$$N_{c,sd} \leq N_{c,Rd} \tag{3.26}$$

Step-2: The Design resistance

$$(N_{c,Rd}) = min(N_{c,Rd1}, N_{c,Rd2}) \tag{3.27}$$

where, ($N_{c,Rd1}$) is the value of the compressive force of the pultruded element and ($N_{c,Rd2}$) is the design compression value.

$$(N_{c,Rd1}) = A.f_{c,d} \tag{3.28}$$

$$(N_{c,Rd2}) = \chi N_{loc,Rd} \tag{3.29}$$

$$(N_{loc,Rd}) = A.f_{loc,d} \tag{3.30}$$

Step-3: Design value of Local Critical Stress

$$f_{loc,d} = \frac{1}{\gamma_f}.min(f_{lockf}, f_{lockw}) \tag{3.31}$$

where, f_{lockf} and f_{lockw} represents, respectively, the critical stress of the uniformly compressed flanges and web

$$(f_{lockf}) = 4.G_{LT}.(\frac{t_f}{b_f})^2 \tag{3.32}$$

$$(f_{lockw}) = K_c.\frac{pi^2.E_{Lc}.(t_w^2)}{12.(1 - v_{LT}.v_{TL}).(b_w)^2} \tag{3.33}$$

$$k_c = 2.\sqrt{\frac{E_{Tc}}{E_{Lc}}} + 4.\frac{G_{LT}}{E_{Lc}}.(1 - (v_{LT})^2.\frac{E_{Tc}}{E_{Lc}}) + 2.v_{LT}\frac{E_{Tc}}{E_{Lc}} \tag{3.34}$$

where, $\frac{E_{Tc}}{E_{Lc}} = 0.3$ and $\frac{G_{LT}}{E_{Lc}} = 0.12$ to 0.17 and $v_{LT} = 0.23$ to 0.35

The minimum value of k_c comes out to be 1.70

$$\chi = \frac{1}{c.(\lambda)^2}).(\phi - \sqrt{(\phi)^2 - c.(\lambda)^2}) \tag{3.35}$$

The value of c = 0.65

$$\phi = \frac{1 + \lambda^2}{2} \tag{3.36}$$

Step-4: Slenderness Ratio

$$\lambda = \sqrt{\frac{N_{loc,Rd}}{N_{Eul}}} \tag{3.37}$$

Step-5: Eulerian Load

$$N_{Eul} = \frac{1}{\gamma_f}.\frac{\pi.E_{eff}.J_{min}}{(L_0)^2} \tag{3.38}$$

The design procedure for tension member is shown below:

Design steps for Tension member

Step-1: Tensile load

$$N_{t,Sd} \leq N_{t,Rd} \tag{3.39}$$

where $N_{t,Rd}$ is:

For Non-Perforated Section

$$N_{t,Rd} = A.f_{td} \tag{3.40}$$

For perforated Section

$$N_{t,Rd} = \frac{1}{\gamma_{Rd}}.A_{net}.f_{td} \tag{3.41}$$

A_{net} is:

$$A_{net} = A - n.t.d \tag{3.42}$$

where, n and d are the number and diameter of holes respectively.

3.3 Summary

In this chapter, design methodology of pedestrian bridge uisng pulturde composites were studied. The design procedure for the pedestrian bridge are explained step by step as per Fiberline Design Manual and National Council of Italy.

Chapter 4

Analysis and Design of a Pedestrian Bridge

4.1 General

Pedestrian bridge is a bridge designed for pedestrians and in some cases cyclists, animal traffic and horse riders instead of a vehicular traffic. In many countries pedestrian bridges can be used for functional as well as for the art and sculpture. In this chapter the analysis and design of beam type and truss type pedestrian bridge using pultruded composites. Various spans for beam type and truss type are also designed and the detailed drawings for the beam type and truss type are shown in this chapter.

4.1.1 Load Considered

The loads considered for the analysis are taken from the "Fiberline Design Manual" guideline for the analysis and design of a Pedestrian bridge. The loads considered are shown in the Table 4.1.

Table 4.1: Loads Considered

Loads	**Values**	**Units**
Dead Load	Seflweight of the Section	kN
Live Load	5	kN/m^2

4.1.2 Load Combination

The load combination are also considered from the "Fiberline Design Manual" guideline and are shown in the Table 4.2.

Table 4.2: Load Combination

Sr.NO	**Load Combination**
1	1.5 (DL)
2	1.5 (LL)
3	1.5 (DL+LL)

4.1.3 Design parameters

The design parameter for the analysis of the bridge are shown below:

- Length of bridge = 3m
- Width of bridge = 1.5m
- Live load = 5 kN/m^2
- Material = Pultruded
- Factor of Safety = 1.5
- Deflection limit = $\frac{L}{300}$

4.2 Beam Type Pedestrian Bridge

The profile of the beam type pedestrian bridge is shown in the Figure 4.1.

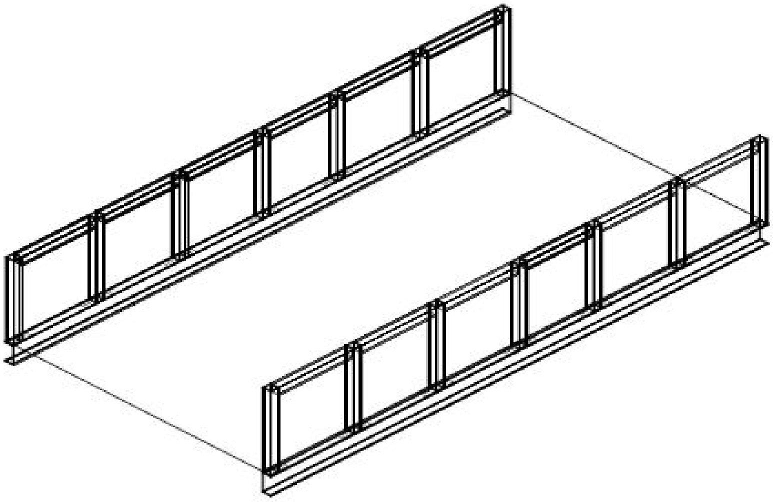


Figure 4.1: Profile of Box type bridge

Total of three sections were considered for the main girders of the pedestrian bridge. The sections were I-Section, C-Section and Box-Section. The height of the railings is 1 m and the sections used for the railings was **Box-Section**. The plan of the beam type pedestrian bridge is shown in Figure 4.2.

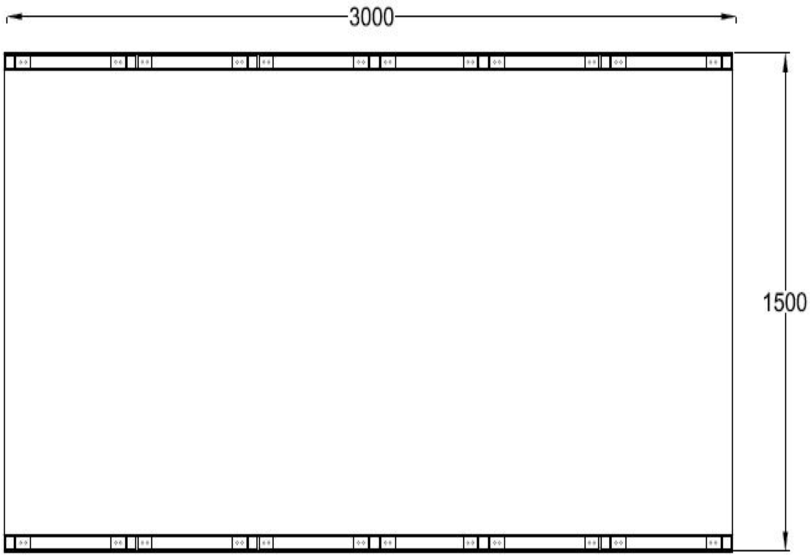


Figure 4.2: Plan of 3m span beam type pedestrian bridge

The elevation of the beam type pedestrian bridge is shown in Figure 4.3.

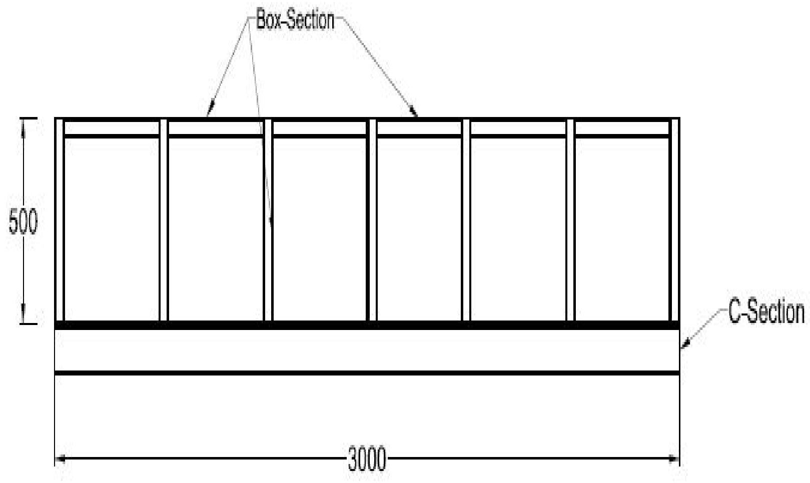


Figure 4.3: Elevation of 3m span beam type pedestrian bridge

4.2.1 Analysis of a Beam type Pedestrian Bridge

The analysis of a Beam Type Pedestrian Bridge was done using Staad-Pro software. In staad pro the material properties of pultruded is not pre defined so the material properties are defined using the material constants command in staad pro. The material properties considered for the analysis is shown in Table 4.3.

Table 4.3: Material Properties

Parameters	**Symbol**	**Values**	**Units**
Modulus of Elasticity	E	38422.7	N/mm^2
Shear Modulus	G	14447	N/mm^2
Poission's Ratio	ν	0.33	

The Figure 4.4 shows the method for assigning the material property in staad pro.
The span length of the beam type pedestrian bridge is 3m and the width is 1m. The height of the bridge is 1m. The staad model is as shown in Figure 4.5.

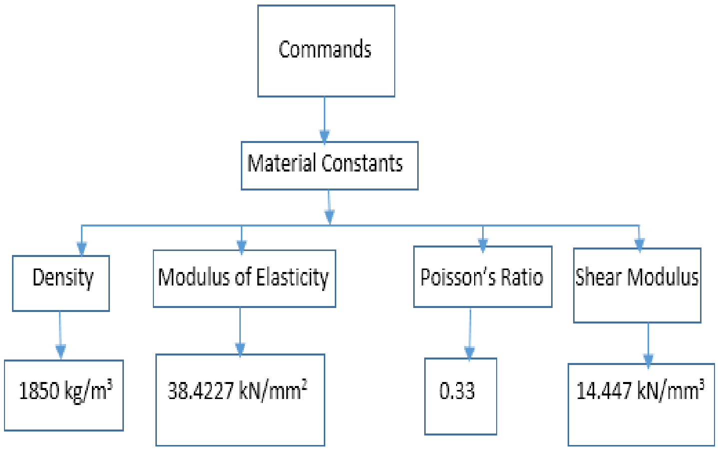


Figure 4.4: Flowchart of Property Assigning

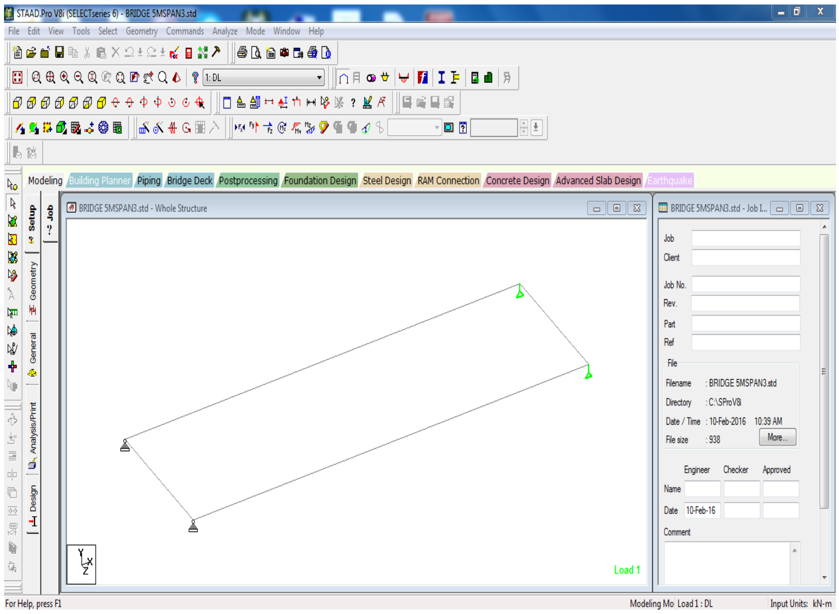


Figure 4.5: Model of Bridge

- The dead load i.e self weight was applied giving factor of "-1" in global Y direction as shown in Figure 4.6.

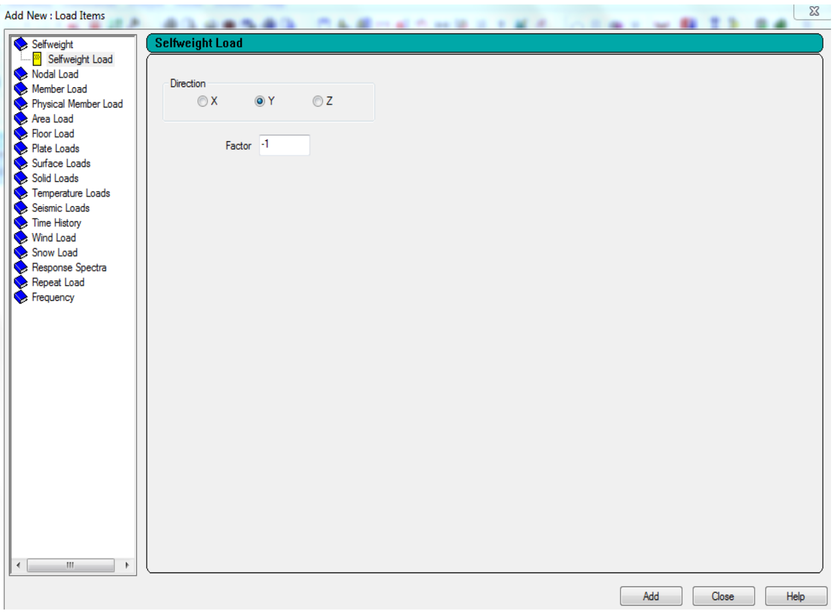


Figure 4.6: Selfweight factor

- The live load of 5 kN/m^2 was applied as the floor load as shown in Figure 4.7.

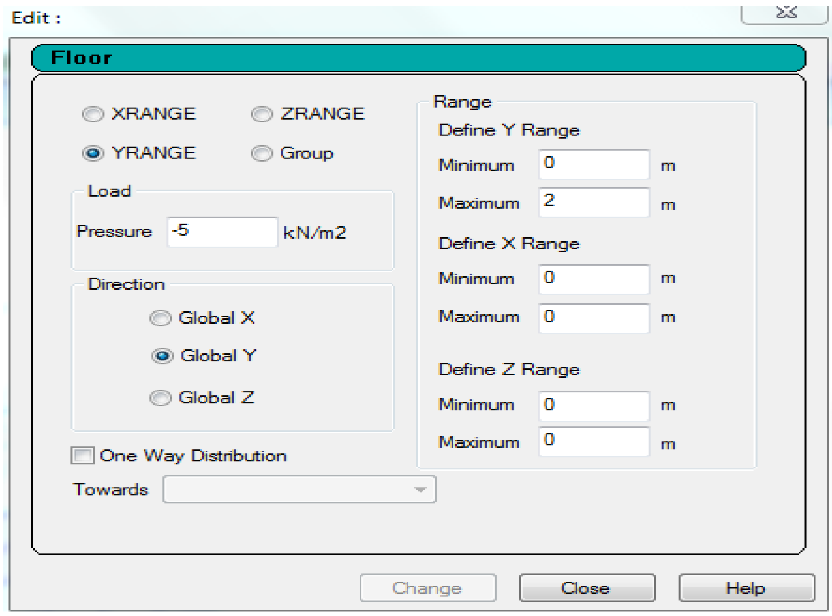


Figure 4.7: Live load of 5 kN/m^2

The analysis results for 3m span beam type pedestrian bridge is shown in the Table 4.4 Similarly the analysis for other span were done and the results of bending moment and shear force are shown in the Table 4.5. The length of the sections available are only upto 10 to 12m so for 15m and 20m the span is divided into two span i.e. 7.5m and 10m respectively.

Table 4.4: Analysis Results for 3m span

Sr.No	**Parameters**	**Values**
1	Moment (kN.m)	6.45
2	Shear Force (kN)	8.6

Table 4.5: Analysis Results for different spans

Spans (m)	**Length (m)**	**Bending Moment (kN.m)**	**Shear Force (kN)**
5	5	17.6	14.06
10	10	70.31	28.13
15	7.5	39.6	21.1
20	10	70.31	28.13

The Table 4.5 shows the analysis results of various spans for beam type pedestrian bridge. The bending moment and Shear force for various spans are shown in the table. The girder is considered as simply supported, so the maximum bending moment is considered at mid span.

4.2.2 Design of Beam Type Pedestrian bridge

The Design of the 3m span pedestrian bridge is done using Fiberline Deign Manual and National Research Council of Itlay.

- Design by Fiberline Design Manual

Design of a 3m span girder

Step-1: Load Calculation

$$q_1 = 3.75 \ kN/m$$

$$Pd = \gamma_{mf} \times q_1 = 1.5 \times 3.75$$

$$P_d = 5.625 \ kN/m$$

Step-2: Moment Calculation

$$M = K_m P_d L^2 = 0.125 \times 5.625 \times 3^2$$

$$M = 6.33 \ kN.m$$

Step-3: Shear Calculation

$$V_d = K_v P_d L = 0.625 \times 5.625 \times 3$$

$$V_d = 10.54 \ kN$$

Total 3 sections were considered for the girder i.e. C-Section,I-Section and Box-Section. The geometric properties of the sections are shown in Figure 5.1.

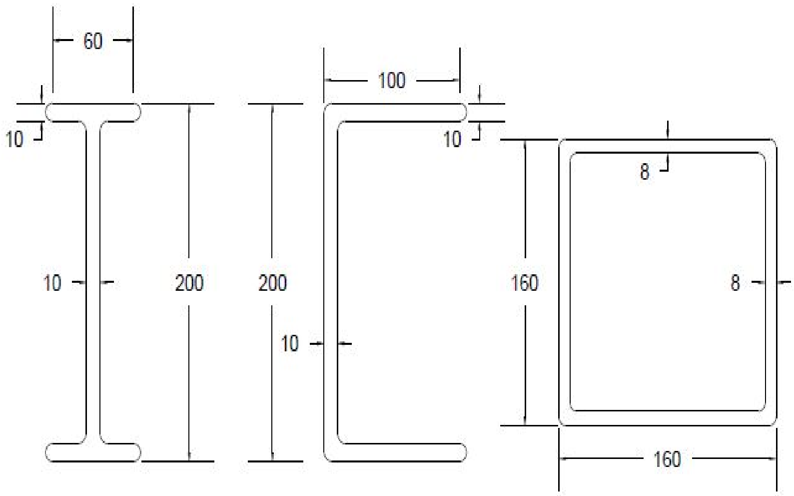


Figure 4.8: Sections Considered for 3m span Girder

The geometric properties of the sections are shown in the Table 4.6

Table 4.6: Geometric Properties of the Sections

Parameters	**Symbols**	**Units**	**C-Section**	**I-Section**	**Box- Section**
Depth of the Section	D	mm	200	200	160
Width of the Section	b_f	mm	60	100	160
Thickness of flange	t_f	mm	10	10	8
Thickness of web	t_w	mm	10	10	8
Cross-Section Area	A	mm^2	3000	3800	4864
Moment of Inertia	I_{xx}	mm^4	15700000	22926666.7	18781525
Section Modulus	W_{xx}	mm^3	157000	229266.66	234769.1

Considering C-Section as the Girder

Step-1: Bending Stress Calculation

$$\sigma_{max} = \frac{M}{W_{xx}} = \frac{6.33 \times 10^6}{157000}$$

Step-2: Permissible Bending Stress

$$\sigma_{max} = 40.32 \ \ N/mm^2 \leq 300 \ \ N/mm^2$$

As the 40.32 N/mm^2 is less than 300 N/mm^2 the section is safe in bending.

Step-3: Shear Stress Calculation

$$\tau_{max} = \frac{V_d}{A_k} = \frac{10.54 \times 10^3}{2000} = 5.27 \ \ N/mm^2$$

Step-4: Permissible Shear Stress

$$\tau_{max} = 5.27 \ \ N/mm^2 \leq 16.67 \ \ N/mm^2$$

As the 5.27 N/mm^2 is less than 16.67 N/mm^2 the section is safe in shear.

Step-5: Deflection Check

$$q_k = \frac{K_{\delta m} q_k L^3}{E I_{xx}} + \frac{K_{\delta v} q_k L}{G A_k} \tag{4.1}$$

The value of $k_{\delta m}$ and $k_{\delta v}$ are given in the fiberline design manual and are shown in the Table 4.7.

Table 4.7: Coefficients for $k_{\delta m}$ and $k_{\delta v}$

Coefficients	One Span	Two Spans	Three Spans
$k_{\delta m}$	0.01302	0.00542	0.00688
$K_{\delta v}$	0.125	0.125	0.125

$$q_k = \frac{0.01302 \times 3.75 \times 3000^4}{38422.7 \times 15700000} + \frac{0.125 \times 3.75 \times 3000^2}{14447 \times 2000}$$

$$q_k = 6.7 \ mm \leq \ 10mm$$

As the 6.7 mm is less than 10 mm the section is safe in deflection.

Therefore the C-Section 200×60×10 is safe as girder.

Similarly for the other sections the girder design was done and the design results are shown in the Table 4.8

Table 4.8: Design results for I-Section and Box-Section

Parameters	Unit	Limit	I-Section	Box-Section
Bending Stress	N/mm^2	300	27.61	26.96
Shear Stress	N/mm^2	16.67	5.27	8.23
Deflection	mm	10	4.57	5.54

The girder design results for the other spans are shown in the Table 4.9. The spans 15m and 20m are two span girder so the length of each span is 7.5m and 10m respectively.

Table 4.9: Girder Design for different spans

Spans (m)	Length of Girder (m)	Span	Sections		
			C-Section	I-Section	Box-Section
5	5	One	300×90×15	300×150×15	240×240×12
10	10	One	400×120×20	300×150×15	300×300×15
15	7.5	Two	300×90×15	300×150×15	240×240×12
20	10	Two	400×120×20	300×150×15	300×300×15

- Design by National Research Council of Italy

Design of 3m span girder

Step-1: Design Moment

$$M_{sd} = 6.33 \ kN.m$$

For the girder the C-Section is selected and the size of the section is 200 × 60 × 10 mm

The Geometric Properties of the section is shown in the Table 4.6

Step-2: Bending Stress

$$W_{xx}.f_{td} = 157000 \times 300$$

$$W_{xx}.f_{td} = 47.1 \ kN.m$$

$$W_{xx}.f_{cd} = 157000 \times 300$$

$$W_{xx}.f_{cd} = 47.1 \ kN.m$$

$$M_{Rd1} = min(W.f_{t,d}, W.f_{c,d})$$

The value of (M_{Rd1}) should be min of $W_{xx}.f_{td}$ and $W_{xx}.f_{cd}$

The value of (M_{Rd1}) is :

$$M_{Rd1} = 47.1 \ kN.m$$

So the value of (M_{sd}) is $\leq$ (M_{Rd1}). So the profile is safe as flexure member.

Step-3: Deflection Check

$$\delta = \frac{5}{384} \times \frac{WL^4}{EJ} \tag{4.2}$$

$$\delta = \frac{5}{384} \times \frac{3.75 \times 3000^4}{38422.7 \times 15700000}$$

$$\delta = 6.55 \ mm \leq 10 \ mm$$

As the design values are less than the permissible values the section is safe as girder.

Design of Columns

- Design by Fiberline Design Manual

For the column the I-Section of 200× 100× 10 mm has been considerd.

The geometric properties of the I-section is shown in the Table 4.6

The length of the column is 2m and the axial load on the column is around 10.45 kN

Step-1: Compressive Load acting on Column

$$N_d = 10.45 \ kN$$

Step-2: Euler Load

$$N_{el} = \frac{\pi^2 EI}{\gamma_m L_k^2} = \frac{\pi^2 \times 38422.7 \times 22926666.7}{1.5 \times 2000^2}$$

$$N_{el} = 1449.1 \ kN$$

Step-3: Compressive Stress

$$\sigma_{el} = \frac{1449.1 \times 10^3}{3800} = 381 \ N/mm^2$$

Step-4: Compressive Load

$$F_d = \frac{3800 \times 450}{1.5} = 1140 \ kN$$

Step-5: Slenderness Ratio

$$\lambda_r = \sqrt{\frac{450}{381 \times 1.5}} = 0.89$$

Step-6: Compressive Load capacity of the Profile

$$N_{cr} = \frac{1140}{1 + 0.89^2} = 636 \ kN$$

As the N_d is less than N_{cr} so the I-Section is suitable for the column. Provide I-section of 200×100×10 as the Column.

• Design by National Research Council of Italy

The length of the column is 2m and the axial load on the column is around 10.45 kN

Step-1: Compressive Load acting on Column

$$N_{c,sd} = 10.45 \ \ kN$$

Step-2: Design Resistance

$$(N_{c,Rd}) = min(N_{c,Rd1}, N_{c,Rd2}) \tag{4.3}$$

where, $(N_{c,Rd1})$ is the value of the compressive force of the pultruded element and $(N_{c,Rd2})$ is the design compression value.

$$(N_{c,Rd1}) = A.f_{c,d} = 3800 \times 300$$

$$(N_{c,Rd1}) = 1140 \ \ kN$$

The value of $k_c = 1.70$

Step-3: Compressive Stress of Web

$$(f_{lockw}) = 1.70 \times \frac{(\pi)^2 \times 38422.7 \times 10^2}{12 \times (1 - 0.33 \times 0.33) \times 100^2}$$

$$(f_{lockw}) = 602.88 \ \ N/mm^2$$

Step-4: Compressive Stress of Flange

$$(f_{lockf}) = 4 \times 14447 \times (\frac{10}{100})^2$$

$$(f_{lockf}) = 577.88 \ \ N/mm^2$$

$f_{locd} = \min(f_{lockf} \ , \ f_{lockw})$

Step-5: Compressive Stress

$$(f_{locd}) = \frac{1}{1.5} \times 577.88$$

$$(f_{locd}) = 385.25 \ \ N/mm^2$$

Step-6: Resistive Compressive Load

$$N_{loc,Rd} = 3800 \times 385.25$$

$$N_{loc,Rd} = 1463.95 \ \ kN$$

Step-7: Euler Load

$$N_{Eul} = \frac{1}{1.5} \times \frac{\pi \times 38422.7 \times 22926666.7}{2000^2}$$

$$N_{Eul} = 461.24 \ \ kN$$

Step-8: Slenderness Ratio

$$\lambda = \sqrt{\frac{1463.95}{461.25}}$$

$$\lambda = 1.78$$

Step-9: Coefficient

$$\phi = \frac{1 + 1.78^2}{2}$$

$$\phi = 2.08$$

Step-10: Coefficient or Reductive Factor

$$\chi = \frac{1}{0.65 \times 1.78^2} \times (2.08 - \sqrt{2.08^2 - 0.65 \times 1.78^2}$$

$$\chi = 0.279$$

$$N_{c,Rd2} = 0.279 \times 1463.95$$

$$N_{c,Rd2} = 408.3 \ \ kN$$

Step-11: Design Compressive Force of the Profile

$N_{c,Rd} = \min(N_{c,Rd1} \ ,N_{c,Rd2})$

$$N_{c,Rd} = 408.3 \ \ kN$$

As $N_{c,sd}$ is less than $N_{c,Rd}$ the profile is safe as column member.

4.3 Truss Type Pedestrian Bridge

The profile of the truss type pedestrian bridge is shown in the Figure 4.9.

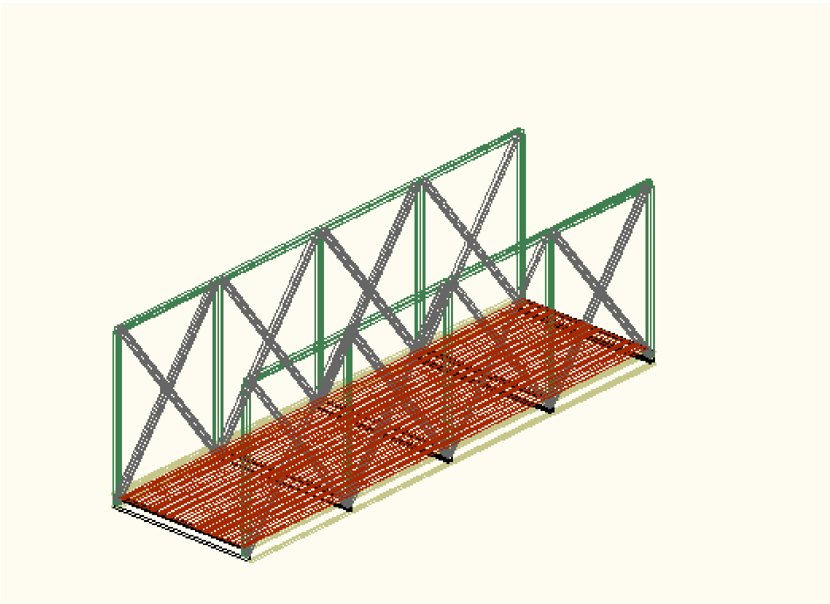


Figure 4.9: Truss type Pedestrian Bridge

Total of two sections were considered for the truss members for the truss type pedestrian bridge. The sections considered for the truss members are Angle Section and Box-Section.The height of the vertical members for the truss type bridge is 1 m. The plan of the truss type pedestrian bridge is shown in Figure 4.10.

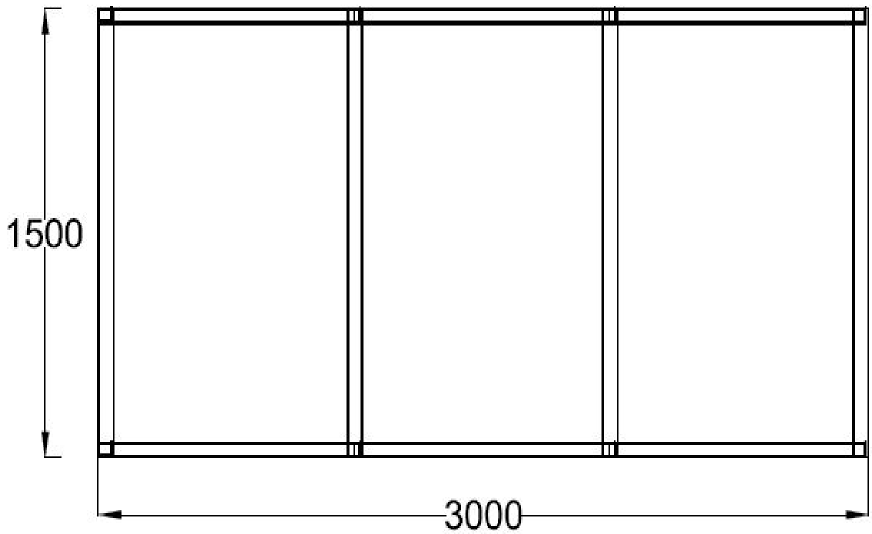


Figure 4.10: Plan of 3m span Truss Type Pedestrian Bridge

The elevation of the Truss type pedestrian bridge is shown in Figure 4.11.

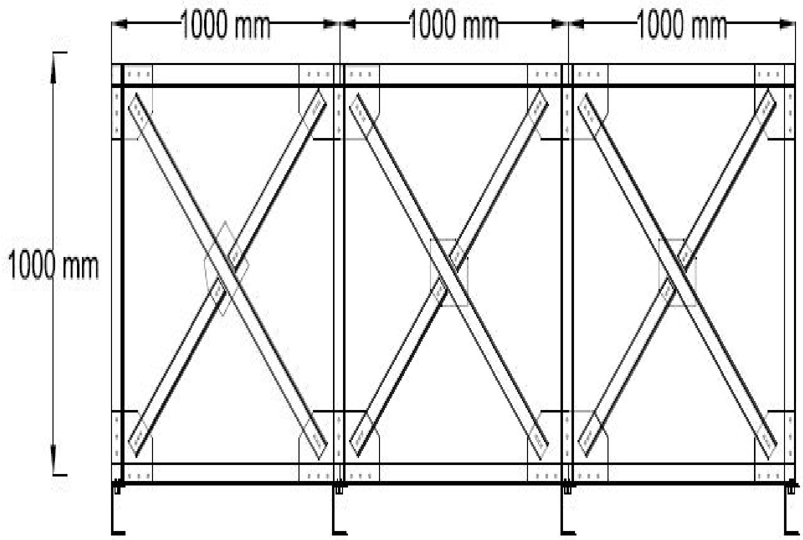


Figure 4.11: Elevation of Truss type Pedestrian bridge

The parameters for a 3m span truss type pedestrian bridge are shown below:

- Length of the pedestrian bridge = 3m
- Width of pedestrian bridge = 1.5m
- Height of the truss system = 1m

- Live load = 5 kN/m^2
- Material = Pultruded
- Factor of Safety = 1.5
- Deflection limit = $\frac{L}{300}$

4.3.1 Analysis of a Truss type Pedestrian Bridge

The analysis of the pedestrian bridge was done using staad pro software the material properties were added manually using material constants commands as shown in Figure 4.4. The staad model of the truss type bridge is shown in the Figure 4.12. The live load of 5 kN/m^2 is applied as shown in the Figure 4.7.

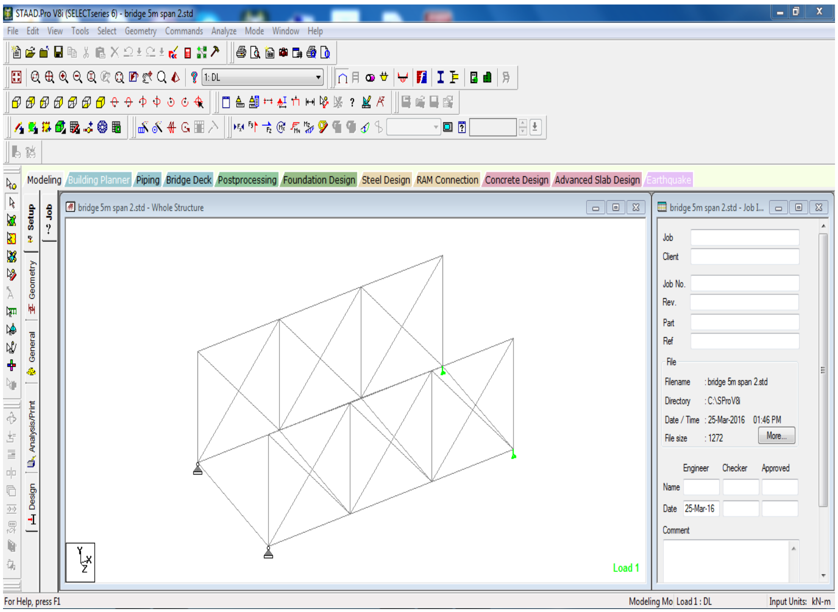


Figure 4.12: Staad model of truss type bridge

The member mark of the 3m span truss type bridge is shown in the Figure 4.13.

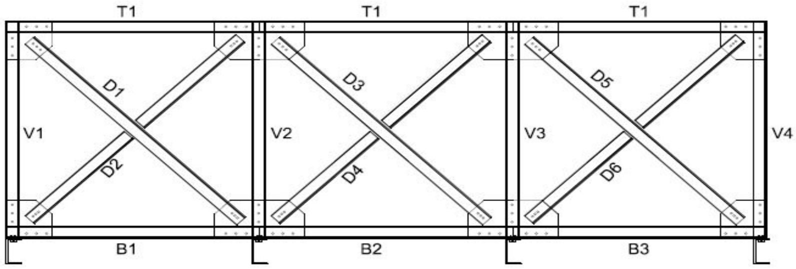


Figure 4.13: Member mark of 3m span bridge

The analysis results of the cross beam for 3m span is shown in the Table 4.10 below:

Table 4.10: Analysis of a Cross Beam for 3m Span truss type Bridge

Span (m)	**Moment (kN.m)**	**Shear Force (kN)**
3	1.93	5.65

The above table shows the analysis result for the cross girder of span 3m. The bending moment and shear force for the cross girder is shown in the above table. The cross girder is simply supported, so the maximum bending moment will be at mid span.

The analysis of the bottom chord members for 3m span is shown in the table 4.11. The bottom chord members are shown in Figure 4.13.

Table 4.11: Analysis Result of Bottom Chord Member for 3m span

Bottom Chord Member	**Tensile Force (kN)**
B1	3
B2	5.21
B3	3

The above table shows the analysis result for the bottom chord of span 3m. The bottom chord members are always in tension.

The analysis result of top chord member for 3m span is shown in table 4.12.The top chord members are shown in Figure 4.13.

Table 4.12: Analysis Result of Top Chord Member for 3m span

Bottom Chord Member	**Compressive Force (kN)**
T1	2.83
T2	6.41
T3	2.83

The above table shows the analysis result for the top chord member of span 3m. The top chord members are always in compression.

The analysis of the Vertical member is shown in the table 4.13.The vertical members are shown in Figure 4.13.

Table 4.13: Analysis result of Vertical member for 3m span

Vertical Member	**Compressive Force (kN)**	**Tensile Force (kN)**
V1	2.86	0
V2‘	0	2.31
V3	0	2.31
V4	2.86	0

The above table shows the analysis result for the vertical member of span 3m. The vertical member will be in compression as well as in tension.

The analysis resut of the diagonal members are shown in the table 4.14.The diagonal members are shown in Figure 4.13.

Table 4.14: Analysis result of diagonal member for 3m span

Diagonal Member	**Compressive Force (kN)**	**Tensile Force (kN)**
D1	0	4
D2	4.18	0
D3	0	0.862
D4	0	0.862
D5	4.18	0
D6	0	4

The above table shows the analysis result for the diagonal member of span 3m. The diagonal member will be in compression as well as in tension.

Similarly the analysis for the different spans was done. The analysis of the cross beams for different spans are shown in the Table 4.15. The length of cross beams for each span is 1.5m.

Table 4.15: Analysis of cross girders for various spans

Span (m)	**Bending Moment (kN.m)**	**Shear Force (kN)**
5	2.11	5.67
10	2.67	7.11
15	2.68	7.15
20	4.29	11.4

The above table shows the analysis result of the cross girder for various spans. The cross girders are simply supported, so the maximum bending moment will be at mid span.

The analysis results for bottom chord member and Top chord member for 5m span is shown in the Table 4.16. The length of the bottom chord and top chord member is 1m.

Table 4.16: Analysis Result of Bottom and Top Chord Members for 5m Span

Bottom Chord Member		**Top Chord Member**	
Member Name	Tensile Force (kN)	Membe Name	Compressive Force (kN)
B1	6.18	T1	5.43
B2	13.9	T2	15.1
B3	17	T3	17.8
B4	13.9	T4	15.1
B5	6.18	T5	5.43

The above table shows the analysis result for the bottom chord member and top chord member of span 5m. The bottom chord members are always in tension, where as top chord members are in compression.

The analysis result of vertical and diagonal member for 5m span are shown in Table 4.17. The length of vertical member is 1m and the length of diagonal member is 1.41m.

Table 4.17: Analysis Result of Vertical and Diagonal Member for 5m span

Vertical Member			**Diagonal Member**		
Member Name	Tensile Force (kN)	Compressive Force (kN)	Member Name	Tensile Force (kN)	Compressive Force (kN)
V1	0	5.48	D1,D10	0	8.72
V2	2.62	0	D2,D9	7.67	0
V3	1.86	0	D3,D8	0	3.28
V4	1.78	0	D4,D7	4.94	0
V5	2.62	0	D5	0.52	0
V6	0	5.48	D6	0.67	0

The above table shows the analysis result for the vertical member and diagonal member of span 5m. Both vertical and diagonal members will be in compression as well as tension.

The analysis result of the bottom chord and top chord member of span 10m are shown in the Table 4.18. The length of bottom chord and top chord member is 1.25m

Table 4.18: Analysis result of Bottom and Top Chord members for span 10m

Bottom Chord Member		**Top Chord Member**	
Member Name	Tensile Force (kN)	Member Name	Compressive Force (kN)
B1	17.2	TI	15.4
B2	43.6	T2	44.9
B3	62.4	T3	63.4
B4	71.6	T4	72.7
B5	71.6	T5	72.7
B6	62.4	T6	63.4
B7	43.6	T7	44.9
B8	17.2	T8	15.4

The above table shows the analysis result for the bottom chord member and top chord member of span 10m. The bottom chord members are always in tension, where as top chord members are in compression.

The analysis result of vertical and diagonal member for 10m span are shown in the Table 4.19. The length of vertical member is 1m where as the length of diagonal member is 1.6m

Table 4.19: Analysis result of Vertical and Diagonal member for 10m span

Vertical Member			**Diagonal Member**		
Member Name	Tensile Force (kN)	Compressive Force (kN)	Member Name	Tensile Force (kN)	Compressive Force (kN)
V1	0	12.5	D1,D16	0	22
V2	3.76	0	D2,D15	19.7	0
V3	2.62	0	D3,D14	0	14
V4	2.7	0	D4,D13	15.7	0
V5	2.7	0	D5	0	8.24
V6	2.7	0	D6,D12	9.64	0
V7	2.62	0	D7,D11	0	2.29
V8	3.76	0	D8,D10	3.7	0
V9	0	12.5	D9	0	2.29

The above table shows the analysis result for the vertical member and diagonal member of span 10m. Both vertical and diagonal members will be in compression as well as tension.

The analysis result of the Bottom chord member and Top chord member for 15m span bridge is shown in the Table 4.20. The length of bottom chord and top chord member is 1.25m

Table 4.20: Analysis Result of Bottom and Top Chord Member for 15m span

Bottom Chord Member		**Top Chord Member**	
Member Name	Tensile Force (kN)	Member Name	Compressive Force (kN)
B1,B12	28.5	T1,T12	25.2
B2,B11	74.9	T2,T11	76.3
B3,B10	114	T3,T10	115
B4,B9	143	T4,T9	144
B5,B8	163	T5,T8	164
B6,B7	173	T6,T7	174

The above table shows the analysis result for the bottom chord member and top chord member of span 15m. The bottom chord members are always in tension, where as top chord members are in compression.

The analysis result of vertical and diagonal member for 15m span are shown in the Table 4.21. The length of vertical member is 1m where as for diagonal member the length is 1.6m

Table 4.21: Vertical and Diagonal member for 15m span

Vertical Member			**Diagonal Member**		
Member Name	Tensile Force (kN)	Compressive Force (kN)	Member Name	Tensile Force (kN)	Compressive Force (kN)
V1,V13	0	20.5	D1,D22	0	36.3
V2	4.34	0	D2,D21	32	0
V3	2.51	0	D3,D20	0	27.1
V4	2.63	0	D4,D19	28.9	0
V5	2.73	0	D5,D18	0	21.1
V6	2.73	0	D6,D17	22.5	0
V7	2.73	0	D7,D16	0	14.9
V8	2.73	0	D8,D15	16.3	0
V9	2.63	0	D9,D14	0	8.65
V10	2.73	0	D10,D13	10.1	0
V11	2.51	0	D11	0	2.45
V12	4.34	0	D12	3.76	0

The above table shows the analysis result for the vertical member and diagonal member of span 15m. Both vertical and diagonal members will be in compression as well as tension.

The analysis result of bottom and top chord member for 20m span bridge is shown in Table 4.22.The length of bottom chord and top chord member is 2m.

Table 4.22: Bottom and Top Chord member for 20m span

Bottom Chord Member		**Top Chord Member**	
Member Name	Tensile Force (kN)	Member Name	Compressive Force (kN)
B1,B10	58.7	T1,T10	56.4
B2,B9	159	T2,T9	160
B3,B8	235	T3,T8	236
B4,B7	286	T4,T7	287
B5,B6	312	T5,T6	313

The above table shows the analysis result for the bottom chord member and top chord member of span 20m. The bottom chord members are always in tension, where as top chord members are in compression.

The analysis result of vertical and diagonal member for 20m span is shown in the Table 4.23.The length of vertical member is 1m and that of diagonal member is 2.24m.

Table 4.23: Vertical and Diagonal member for 20m span

Vertical Member			**Diagonal Member**		
Member Name	Tensile Force (kN)	Compressive Force (kN)	Member Name	Tensile Force (kN)	Compressive Force (kN)
V1,V11	0	28.8	D1,D20	0	64.8
V2	6.07	0	D2,D19	62.2	0
V3	5.22	0	D3,D18	0	48.9
V4	5.24	0	D4,D17	50.2	0
V5	5.24	0	D5,D16	0	34.8
V6	5.24	0	D6,D15	36	0
V7	5.24	0	D7,D14	0	20.7
V8	5.24	0	D8,D13	21.9	0
V9	5.22	0	D9,D12	0	6.54
V10	6.07	0	D10,D11	7.74	0

The above table shows the analysis result for the vertical member and diagonal member of span 20m. Both vertical and diagonal members will be in compression as well as tension.

4.3.2 Design of Truss Type Pedestrian Bridge

The design of a 3m truss type pedestrian bridge is shown. The design is done by using Fiberline Design Manual and National Research Council of Italy.

- Design by Fiberline Design Manual

Design of Cross Girders

The analysis result for the cross girder for 3m span truss type pedestrian bridge is:

The bending moment = 1.93 kN.m

Shear Force = 5.64 kN

The material properties are shown in the Table **??**.

Total 3 sections were considered for the girder i.e. **C-Section**,**I-Section** and **Box-Section**

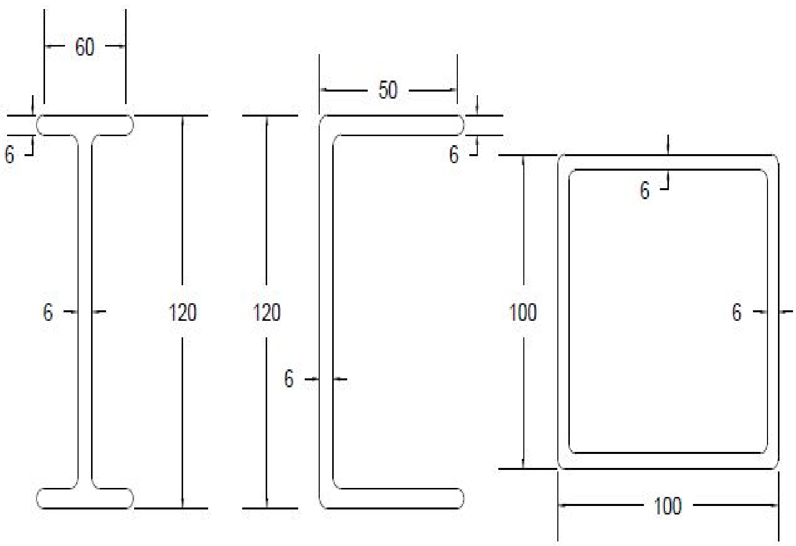


Figure 4.14: Sections Considered for 3m span Cross Girder

The geometric Properties of the sections are shown in the Table 4.24

Table 4.24: Geometric Properties

Parameters	**Symbols**	**Units**	**C-Section**	**I-Section**	**Box-Section**
Depth of Section	D	mm	120	120	100
Width of Section	b_f	mm	50	60	100
Thickness of Flange	t_f	mm	6	6	6
Thickness of Web	t_w	mm	6	6	6
Cross-Section Area	A	mm^2	1248	1368	2256
Moment of Inertia	I_{xx}	mm^4	2581056	2971296	3335872
Section Modulus	W_{xx}	mm^3	43017.6	49521.6	66717.44

Considering C-Section the design of the Cross girder is shown below:

Step-1: Bending Stress Calculation

$$\sigma_{max} = \frac{M}{W_{xx}} = \frac{1.93 \times 10^6}{43017.6}$$

$$\sigma_{max} = 45.56 \ \ N/mm^2 \leq 300 \ \ N/mm^2$$

Step-2: Shear Stress Calculation

$$\tau_{max} = \frac{V_d}{A_k} = \frac{5.64 \times 10^3}{720}$$

$$\tau_{max} = 7.83 \ \ N/mm^2 \leq 16.67 \ \ N/mm^2$$

Step-3: Deflection Check

$$q_k = \frac{K_{\delta m} q_k L^3}{EI_{xx}} + \frac{K_{\delta v} q_k L}{GA_k} \tag{4.4}$$

The value of $k_{\delta m}$ and $k_{\delta v}$ are given in the fiberline design manual and are shown in the Table 4.7.

$$q_k = \frac{0.01302 \times 5 \times 1500^4}{38422.7 \times 2581056} + \frac{0.125 \times 5 \times 1500^2}{14447 \times 720}$$

$$q_k = 3.45 \ \ mm \leq 5 \ \ mm$$

So the C-section is safe as Cross girder.

Similarly for the other spans the girder are designed and the results are shown in Table 4.25.

Table 4.25: Cross Girder design for various spans

Spans (m)	**Length of the Girder (m)**	**C-Section**
5	1.5	120×50×6 mm
10	1.5	120×50×6 mm
15	1.5	120×50×6 mm
20	1.5	120×50×6 mm

Design of Top Chord member

The Top chord member of the truss section is always in compression and hence the design for compression is done for top chord member for 3m span truss type pedestrian bridge. The maximum Compressive load on Top chord member is 6.41 kN.

For the Design of Top chord member the Angle Section and Box-Section has been considered. The section selected for the Top chord member are shown in Figure 5.19.

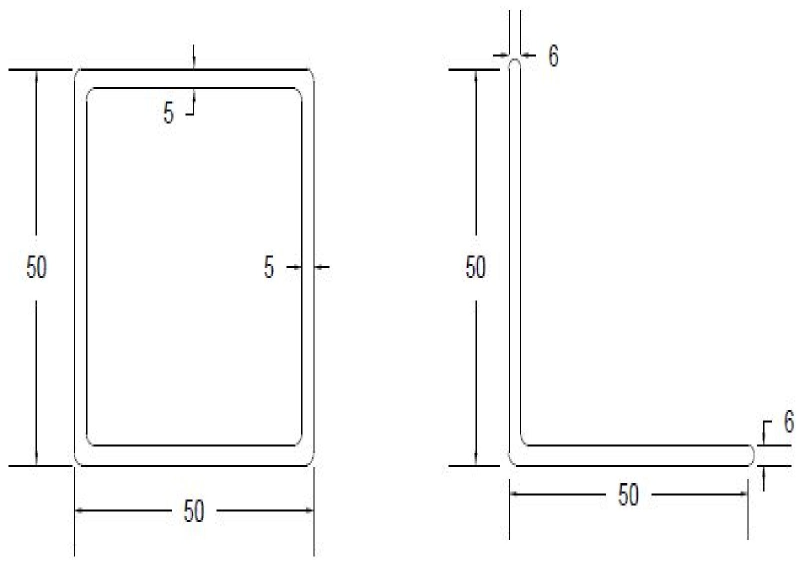


Figure 4.15: Sections Considered for Top Chord Member

The geometric properties of the angle and box section are shown in the Table 4.26.

Table 4.26: Geometric properties of Angle and Box Section

Parameters	**Symbols**	**Units**	**Angle Section**	**Box-Section**
Depth of Section	D	mm	50	50
Width of Section	B	mm	50	50
Thickness	T	mm	6	5
Cross-Section Area	A	mm2	564	900
Moment of Inertia	I	mm4	129945.4	307500
Section Modulus	W	mm3	3681.39	12300

The length of the member is 1m and the axial load on the member is 6.41 kN.

Step-1: Compressive Load acting on member

$$N_d = 6.41 \ \ kN$$

Step-2: Euler Load

$$N_{el} = \frac{\pi^2 EI}{\gamma_m L_k^2} = \frac{\pi^2 \times 38422.7 \times 129945.4}{1.5 \times 1000^2}$$

$$N_{el} = 32.85 \ \ kN$$

Step-3: Stress Calculation

$$\sigma_{el} = \frac{32.85 \times 10^3}{564} = 58.24 \ \ N/mm^2$$

Step-4: Compression Load

$$F_d = \frac{564 \times 450}{1.5} = 169.2 \ \ kN$$

Step-5: Slenderness Ratio

$$\lambda_r = \sqrt{\frac{450}{58.24 \times 1.5}} = 2.27$$

Step-6: Design Compressive Load

$$N_{cr} = \frac{169.2}{1 + 2.27^2} = 27.5 \ \ kN$$

As the Nd is less than N_{cr} so the Angle-Section is suitable for the Compression Member.
Provide Angle-section of 50×50×6 mm as the Top Chord Member.
Similarly the design of top chord member with box-section has been done.

Design of Bottom Chord Member

The Bottom chord member of the truss section is always in tension and hence the design for tension is done for bottom chord member for 3m span truss type pedestrian bridge.
The length of the bottom chord member is 1m and the tensile load is 5.21 kN.
The sections considered for the design are shown in Figure 5.19.
The material properties of the sections are given in the Table 4.26.
The design of tension member is given by:

Step-1: Tensile Load acting on the member

$$N_d = \ 5.21 \ kN$$

Step-2: Resistive Tensile Load

$$\frac{A.f_t}{\gamma_m} = \frac{564 \times 300}{1.5}$$

$$\frac{A.f_t}{\gamma_m} = 112.8 \ kN$$

Hence $N_d \leq$ 112.8 kN, The angle section is safe as Tension Member.

Design of Vertical and Diagonal member

The vertical and diagonal member of the truss member are in both compression and tension. So the diagonal and vertical member are designed for tension as well as compression.
The Table 4.27 shows the maximum compression and tension value for the diagonal and vertical member:

Table 4.27: Maximum Loads in Vertical and Diagonal members

Members	Maximum Compressive Load	Maximum Tensile Load
Vertical	2.89 kN	2.32 kN
Diagonal	4.21 kN	4 kN

As the values of compression and tension member is less than than design values shown in clause 4.4.2 and clause 4.4.3 the angle section 50 × 50 × 6 mm is safe as vertical and diagonal member.

- Design by National Research Council of Italy

Design of Cross Girders

The analysis result for the cross girder for 3m span truss type pedestrian bridge is:

The bending moment = 1.93 kN.m

Shear Force = 5.64 kN

For the girder the C-Section is selected and the size of the section is 120 × 50 × 6 mm.

The Geometric Properties of the section is shown in the Table 4.6.

Step-1: Resistive Moment 1

$$W_{xx}.f_{td} = 43017.6 \times 300$$

$$W_{xx}.f_{td} = 12.90 \ kN.m$$

Step-2: Resistive Moment 2

$$W_{xx}.f_{cd} = 43017.6 \times 300$$

$$W_{xx}.f_{cd} = 12.90 \ kN.m$$

The value of (M_{Rd1}) should be min of $W_{xx}.f_{td}$ and $W_{xx}.f_{cd}$

The value of (M_{Rd1}) is :

$$M_{Rd1} = 12.90 \ \ kN.m$$

So the value of (M_{sd}) is $\leq (M_{Rd1})$. So the profile is safe as flexure member.

Step-3: Deflection Check

$$\delta = \frac{5}{384} \times \frac{WL^4}{EJ} \tag{4.5}$$

$$\delta = \frac{5}{384} \times \frac{5 \times 1500^4}{38422.7 \times 2581056}$$

$$\delta = 3.33 \ \ mm \leq 5 \ \ mm$$

Design of Top Chord Member

The length of the top chord member is 1m and the axial load is 6.41 kN.

Step-1: Compressive Load acting on Column

$$N_{c,sd} = 6.41 \ \ kN$$

Step-2: Design Resistance

$$(N_{c,Rd}) = min(N_{c,Rd1}, N_{c,Rd2}) \tag{4.6}$$

where $(N_{c,Rd1})$ is the value of the compressive force of the pultruded element and $(N_{c,Rd2})$ is the design compression value.

$$(N_{c,Rd1}) = A.f_{c,d} = 564 \times 300$$

$$(N_{c,Rd1}) = 169.2 \ \ kN$$

The value of $k_c = 1.70$

Step-3: Compressive Stress on Web

$$(f_{lockw}) = 1.70 \times \frac{(\pi)^2 \times 38422.7 \times 6^2}{12 \times (1 - 0.33 \times 0.33) \times 50^2}$$

$$(f_{lockw}) = 510.67 \;\; N/mm^2$$

Step-4: Compressive Stress on Flange

$$(f_{lockf}) = 4 \times 14447 \times (\frac{6}{50})^2$$

$$(f_{lockf}) = 832.15 \;\; N/mm^2$$

$f_{loc,d} = \min(f_{loc,w}, f_{loc,f})$

Step-5: Compressive Stress

$$(f_{locd}) = \frac{1}{1.5} \times 832.15$$

$$(f_{locd}) = 554.8 \;\; N/mm^2$$

Step-6: Resistive Compressive Load

$$N_{loc,Rd} = 564 \times 510.67$$

$$N_{loc,Rd} = 288.02 \;\; kN$$

Step-7: Euler Load

$$N_{Eul} = \frac{1}{1.5} \times \frac{\pi \times 38422.7 \times 129945.4}{1000^2}$$

$$N_{Eul} = 10.46 \;\; kN$$

Step-8: Slenderness Ratio

$$\lambda = \sqrt{\frac{288.02}{10.46}}$$

$$\lambda = 5.25$$

Step-9: Coefficient

$$\phi = \frac{1 + 5.25^2}{2}$$

$$\phi = 14.3$$

Step-10: Reductive Factor

$$\chi = \frac{1}{0.65 \times 5.25^2} \times (14.3 - \sqrt{14.3^2 - 0.65 \times 5.25^2}$$

$$\chi = 0.036$$

Step-11: Design Compression Value

$$N_{c,Rd2} = 0..036 \times 288.02$$

$$N_{c,Rd2} = 10.30 \ \ kN$$

Step-12: Design Compression Force of the Profile

$$N_{c,Rd} = 10.30 \ \ kN$$

As $N_{c,sd}$ is less than $N_{c,Rd}$ the profile is safe as compression member.

Design of Bottom Chord Member

The elements subjected to axial tensile load should satisfy the following limitation:

Step-1: Tensile load acting on the profile

$$N_{t,Sd} \leq N_{t,Rd} \tag{4.7}$$

where $N_{t,Rd}$ is:

For Non-Perforated Section

$$N_{t,Rd} = A.f_{td} \tag{4.8}$$

For perforated Section

$$N_{t,Rd} = \frac{1}{\gamma_{Rd}}.A_{net}.f_{td} \tag{4.9}$$

where, A_{net} is:

$$A_{net} = A - n.t.d \tag{4.10}$$

where, n and d are the number and diameter of holes respectively.

Step-2: Tensile Load

$$N_{t,Sd} = 5.21 \ kN$$

Considering the perforated section:

Assuming 2 number of holes having diameter of 12 mm

so n=2 and d=12

Step-3: Net Area Calculation

$$A_{net} = 564 - 2 \times 6 \times 12$$

$$A_{net} = 420 \ mm^2$$

Step-4: Resistive Tensile Load

$$N_{t,Rd} = \frac{1}{1.5} \times 420 \times 450$$

$$N_{t,Rd} = 126 \ kN$$

As $N_{t,Sd} \leq N_{t,Rd}$ the angle section is safe as tension member.

4.4 Summary

In this chapter the analysis of beam type and truss type pedestrian bridge is done using staad pro software. The design of beam type and truss type pedestrian bridge is done using pultruded composites. The design of 3m span for beam type and truss type pedestrian bridge is done using fiberline design manual and national research council of Italy.

Chapter 5

Parametric Study

5.1 General

In this section the comparison of the Pultruded composites with steel is done. Also the comparison of pultruded sections are done i.e for beam type pedestrian bridge the sections used for girders are compared with each other and similarly for truss type pedestrian bridge the sections are compared with each other. For the beam type pedestrian bridge the moment capacity is fixed and the different parameters are compared. Similarly for the truss type pedestrian bridge the axial force is kept constant and other parameters are compared.

5.2 Comparison of Pultruded composites sections

The comparison of pultruded sections is done to investigate which sections proves to be the better in shear capacity, deflection and cost efficiency. The cost of the pultruded composites is around rupees 150 to rupees 180 per kg as per the Fibertech Composites manufacturing unit situated at ahmedabad. This cost is only the fabrication cost. The cost of transportation and labour cost are not considered.

5.2.1 Beam type Pedestrian Bridge

For beam type pedestrian bridge the sections used for the girder are C-Section, I-Section and Box-Section.

- **3m span Pedestrian Bridge**

The geometric properties of the sections are shown in Figure 5.1.

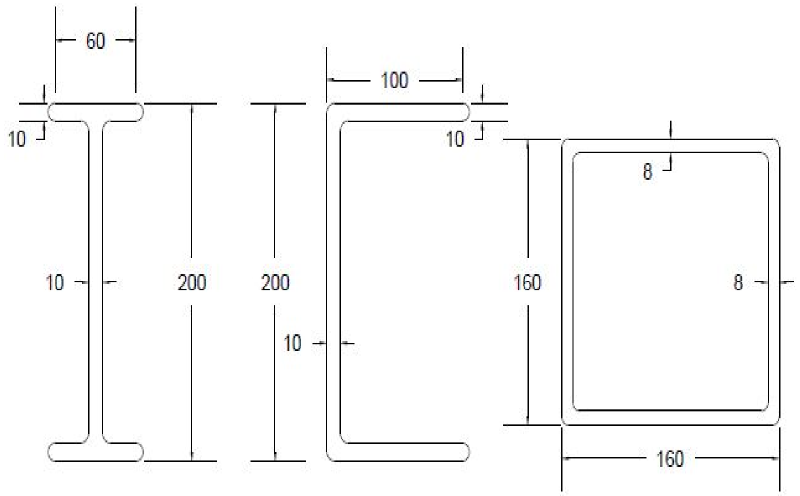


Figure 5.1: Sections Considered for 3m span Girder

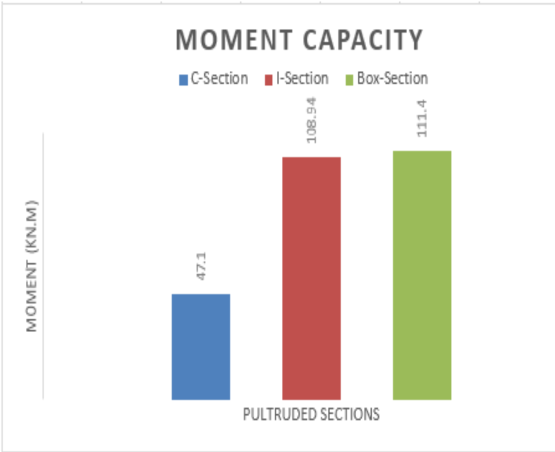
The geometric properties of the sections are shown in the Table 4.6
The comparison of the different parameters for the different sections are shown in the Table 5.1.

Table 5.1: Comparison of Sections

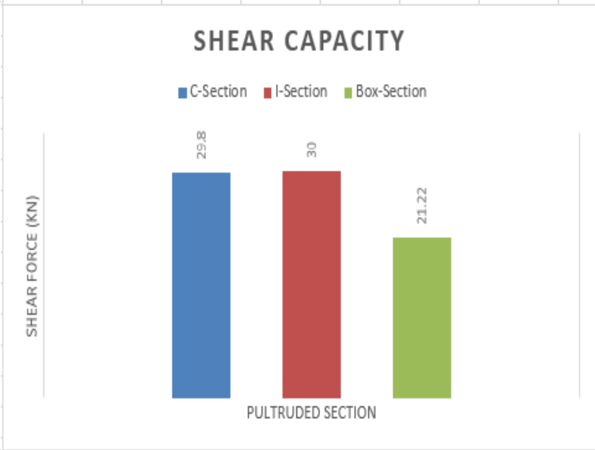
Parameters	**C-Section**	**I-Section**	**Box-Section**
Moment Capacity (kN.m)	47.1	108.94	111.4
Shear Capacity (kN)	29.8	30	21.22
Deflection (mm)	7.03	4.86	5.77
Weight (kg)	16.65	21.09	27

The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is less than I and C sections. The deflection of Box-section is less than I and C sections. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in Figure 5.2



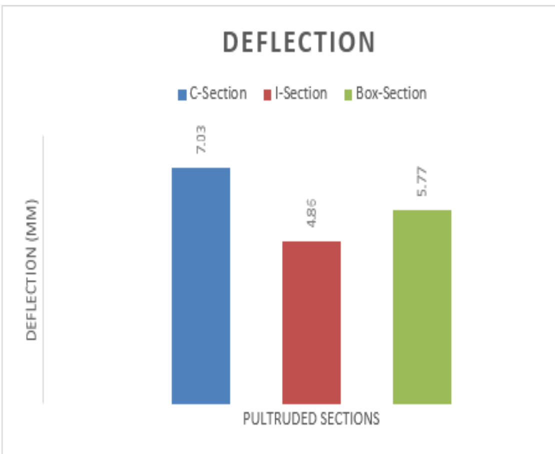
(a) Moment Capacity Comparison



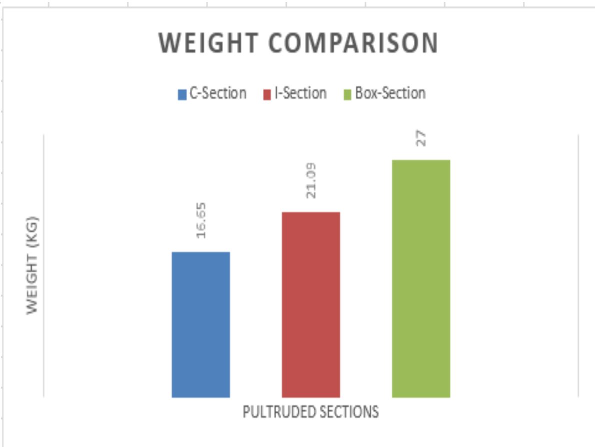
(b) Shear Capacity Comparison

Figure 5.2: Comparison of Moment and Shear Capacities for 3m span

The graphical representation of deflection and weight are shown in Figure 5.3



(a) comparison of deflection



(b) comparison of weight

Figure 5.3: Comparison of deflection and weight for 3m span

- **5m span Pedestrian Bridge**

The sections considered for 5m span beam type pedestrian bridge are shown in Figure 5.10.

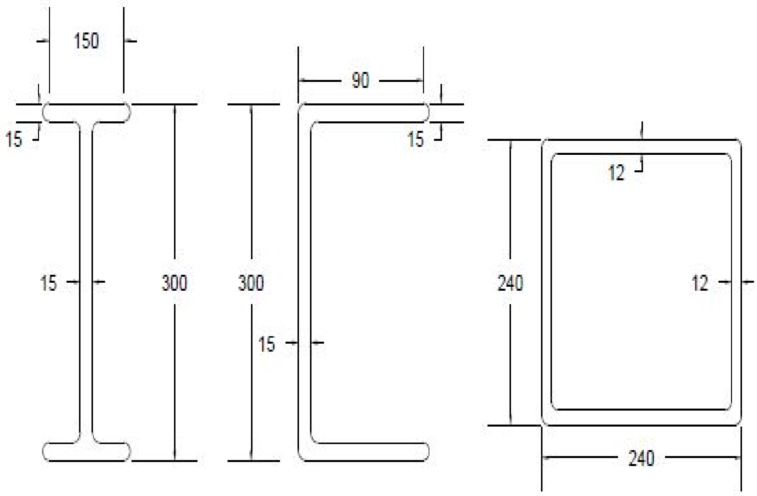


Figure 5.4: Sections Considered for 5m span Girder

The geometric properties of the sections are shown in the Table 5.2

Table 5.2: Geometric Properties of the Sections

Parameters	Symbols	Units	C-Section	I-Section	Box- Section
Depth of the Section	D	mm	300	300	240
Width of the Section	b_f	mm	90	150	240
Thickness of flange	t_f	mm	15	15	12
Thickness of web	t_w	mm	15	15	12
Cross-Section Area	A	mm^2	6750	8550	4864
Moment of Inertia	I_{xx}	mm^4	79481250	116066250	95081472
Section Modulus	W_{xx}	mm^3	529875	773775	792345.6

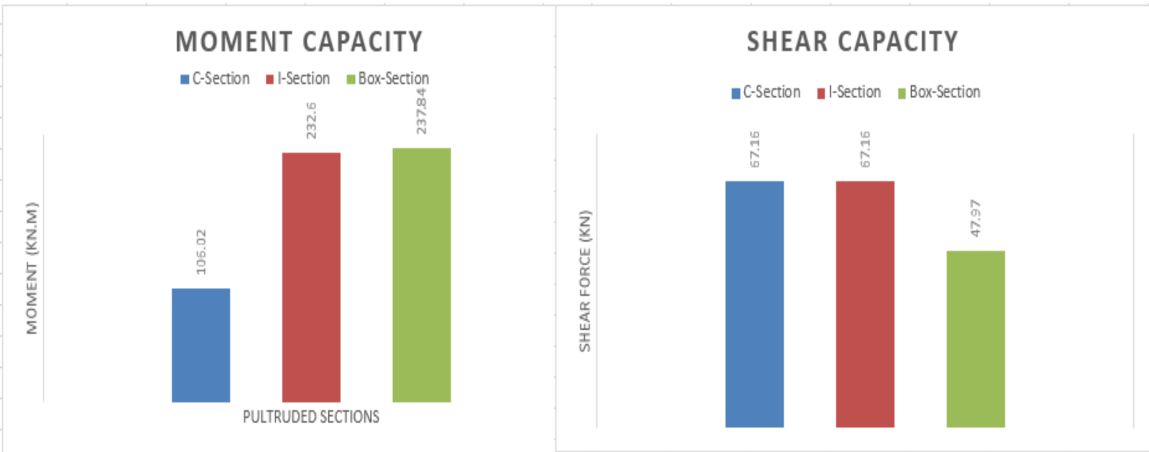
The comparison of the different parameters for the different sections are shown in the Table 5.3.

Table 5.3: Comparison of Sections

Parameters	C-Section	I-Section	Box-Section
Moment Capacity (kN.m)	106.02	232.6	237.84
Shear Capacity (kN)	67.16	68	47.97
Deflection (mm)	10.06	6.94	8.43
Weight (kg)	62.5	79.1	101.25

The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is less than I and C sections. The deflection of Box-section is more than I-section and less than C-section. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in Figure 5.5

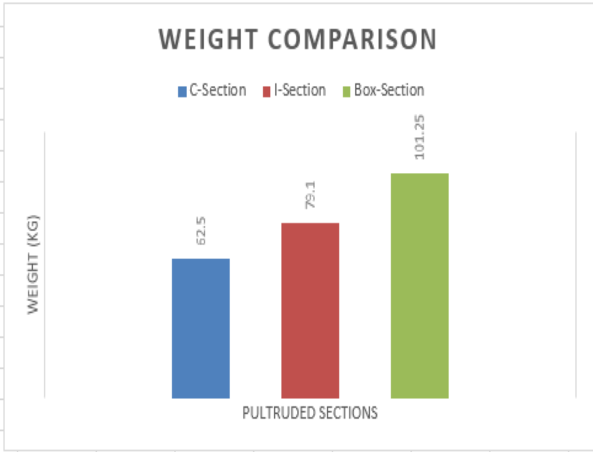


(a) Moment Capacity Comparison (b) Shear Capacity Comparison

Figure 5.5: Comparison of Moment and Shear Capacities for 5m span

The graphical representation of deflection and weight are shown in Figure 5.6

(a) comparison of deflection



(b) comparison of weight

Figure 5.6: Comparison of deflection and weight for 5m span

- **10m span Pedestrian Bridge**

The sections considered for 10m span beam type pedestrian bridge are shown in Figure 5.7.

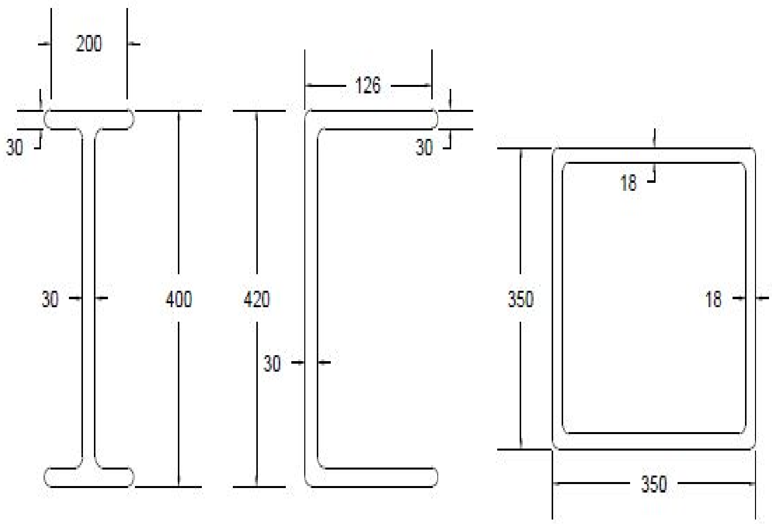


Figure 5.7: Sections Considered for 10m span Girder

The geometric properties of the sections are shown in the Table 5.4

Table 5.4: Geometric Properties of the Sections

Parameters	**Symbols**	**Units**	**C-Section**	**I-Section**	**Box- Section**
Depth of the Section	D	mm	420	400	350
Width of the Section	b_f	mm	126	200	350
Thickness of flange	t_f	mm	30	25	18
Thickness of web	t_w	mm	30	25	18
Cross-Section Area	A	mm^2	18360	18750	23904
Moment of Inertia	I_{xx}	mm^4	405000000	441406250	440000000
Section Modulus	W_{xx}	mm^3	1927029	2207031.25	2516704

The comparison of the different parameters for the different sections are shown in the Table 5.5.

Table 5.5: Comparison of Sections

Parameters	**C-Section**	**I-Section**	**Box-Section**
Moment Capacity (kN.m)	577.81	661.13	756
Shear Capacity (kN)	180.13	146.4	104.1
Deflection (mm)	31.45	28.96	28.99
Weight (kg)	340	346.9	442.2

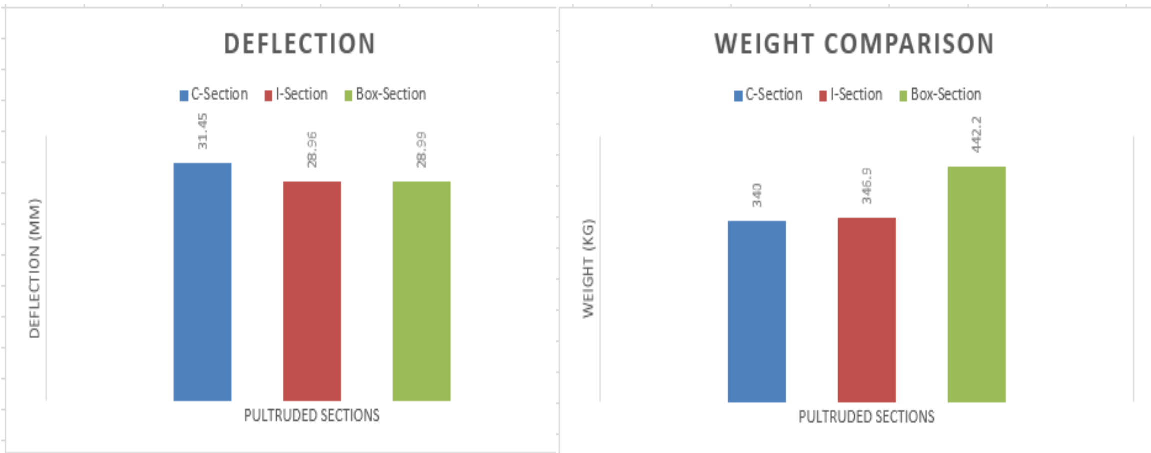
The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is less than I and C sections. The deflection of Box-section is less than I and C sections. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in Figure 5.8

(a) Moment Capacity Comparison (b) Shear Capacity Comparison

Figure 5.8: Comparison of Moment and Shear Capacities for 10m span

The graphical representation of deflection and weight are shown in Figure 5.9



(a) comparison of deflection (b) comparison of weight

Figure 5.9: Comparison of deflection and weight for 10m span

- **15m span Pedestrian Bridge**

As the sections are available upto a length of 10 to 12 mts, the lenght of girder for 15m span is 7.5m. So the 15m span pedestrian bridge is a two span 7.5m pdestrian bridge. The sections considered for the girders are shown below:

The sections considered for 15m span beam type pedestrian bridge are shown in Figure 5.10.

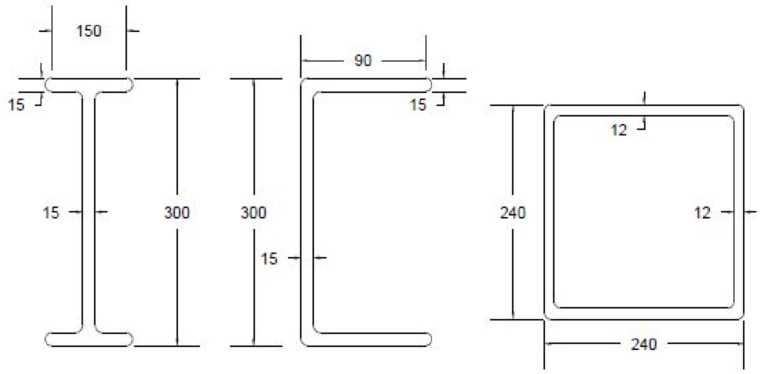


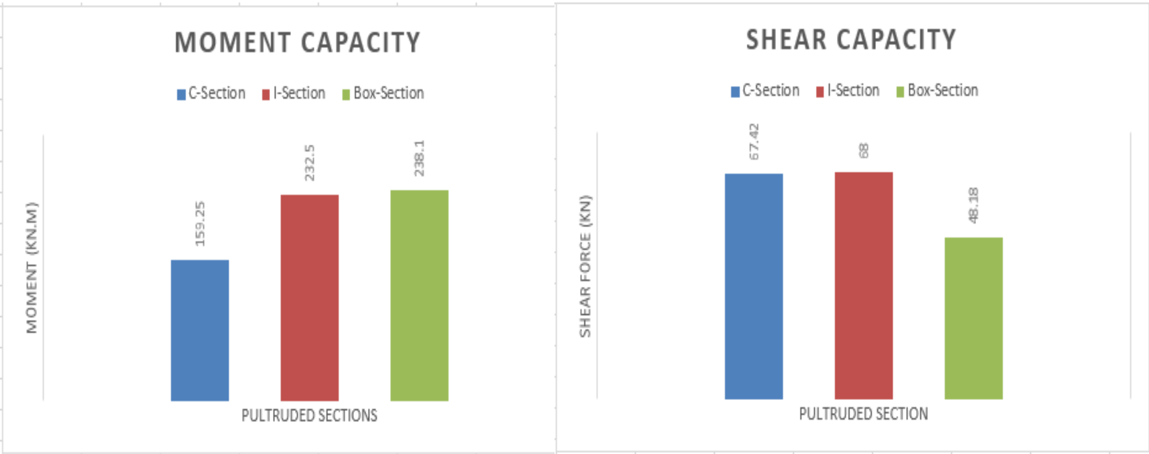
Figure 5.10: Sections Considered for 15m span Girder

The geometric properties of the sections are shown in the Table 5.2
The comparison of the different parameters for the different sections are shown in the Table 5.6.

Table 5.6: Comparison of Sections

Parameters	**C-Section**	**I-Section**	**Box-Section**
Moment Capacity (kN.m)	159.25	232.5	238.1
Shear Capacity (kN)	67.42	68	48.18
Deflection (mm)	21.17	14.63	17.77
Weight (kg)	93.75	118.88	151.88

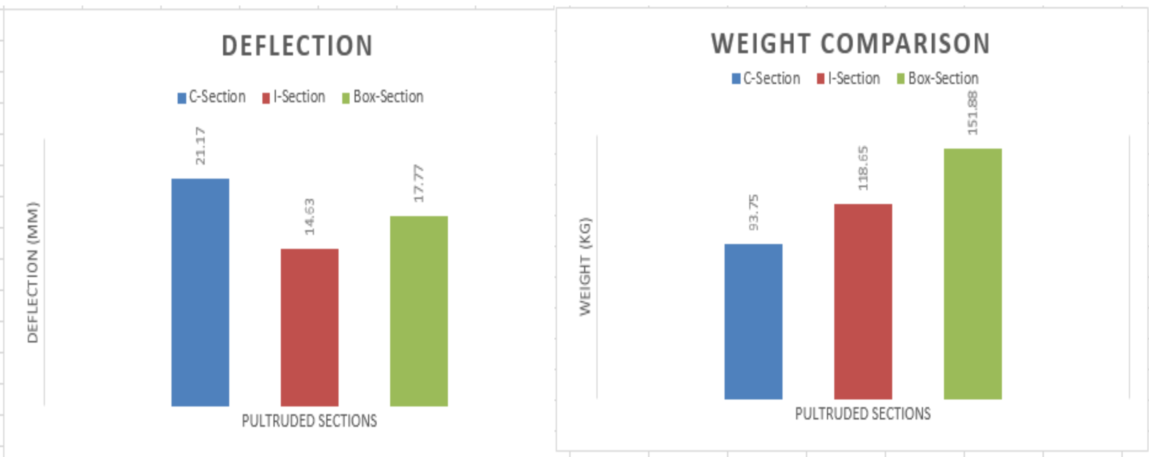
The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is less than I and C sections. The deflection of Box-section is less than C-section but more than I-Section. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.
The graphical representation of moment and shear capacities are shown in Figure 5.11



(a) Moment Capacity Comparison (b) Shear Capacity Comparison

Figure 5.11: Comparison of Moment and Shear Capacities for 15m span

The graphical representation of deflection and weight are shown in Figure 5.12



(a) comparison of deflection (b) comparison of weight

Figure 5.12: Comparison of deflection and weight for 15m span

- **20m span Pedestrian Bridge**

As the sections are available upto a length of 10 to 12 mts, the lenght of girder for 20m span is 10m. So the 20m span pedestrian bridge is a two span 10m pdestrian bridge. The sections considered for 20m span beam type pedestrian bridge are shown in Figure 5.13.

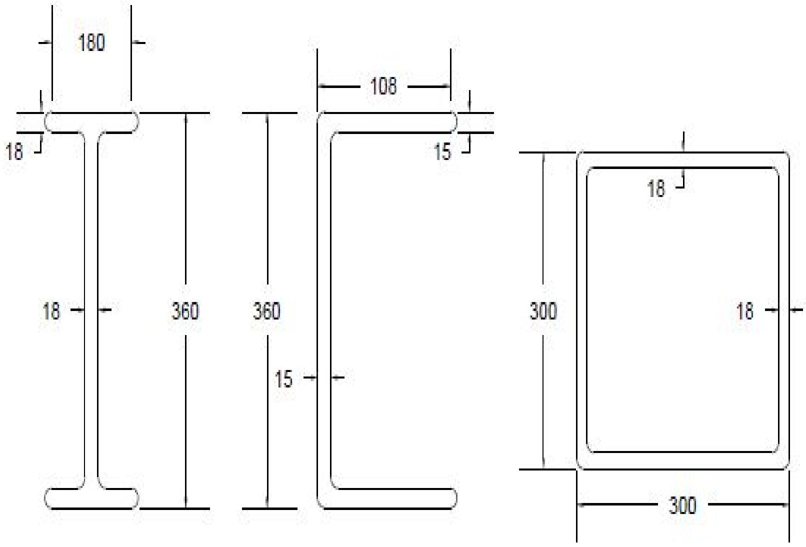


Figure 5.13: Sections Considered for 20m span Girder

The geometric properties of the sections are shown in the Table 5.7

Table 5.7: Geometric Properties of the Sections

Parameters	**Symbols**	**Units**	**C-Section**	**I-Section**	**Box- Section**
Depth of the Section	D	mm	360	360	300
Width of the Section	b_f	mm	108	180	300
Thickness of flange	t_f	mm	15	18	15
Thickness of web	t_w	mm	15	18	15
Cross-Section Area	A	mm^2	8192	12312	17100
Moment of Inertia	I_{xx}	mm^4	141000000	240674976	232000000
Section Modulus	W_{xx}	mm^3	785512.5	1337083.2	1547550

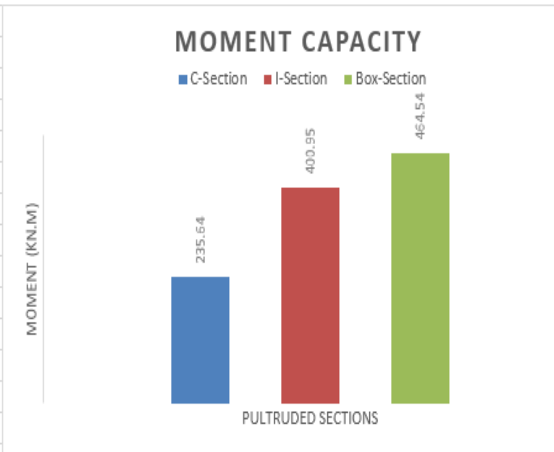
The comparison of the different parameters for the different sections are shown in the Table 5.8.

Table 5.8: Comparison of Sections

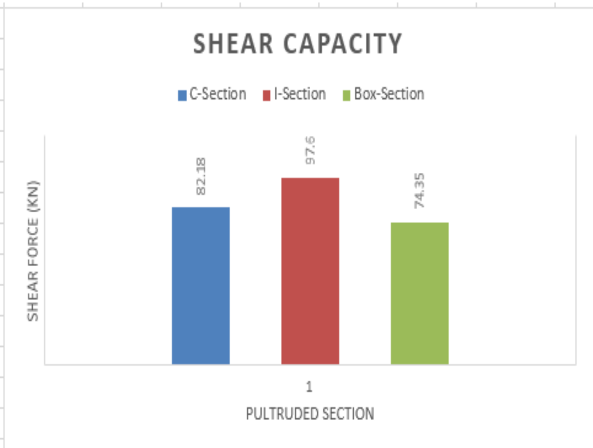
Parameters	C-Section	I-Section	Box-Section
Moment Capacity (kN.m)	235.64	400.95	464.54
Shear Capacity (kN)	82.18	97.6	74.35
Deflection (mm)	28.15	22.25	22.98
Weight (kg)	151.5	228	316.4

The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is less than I and C sections. The deflection of Box-section is less than C-section but is nearly equal to I-Section. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in Figure 5.14



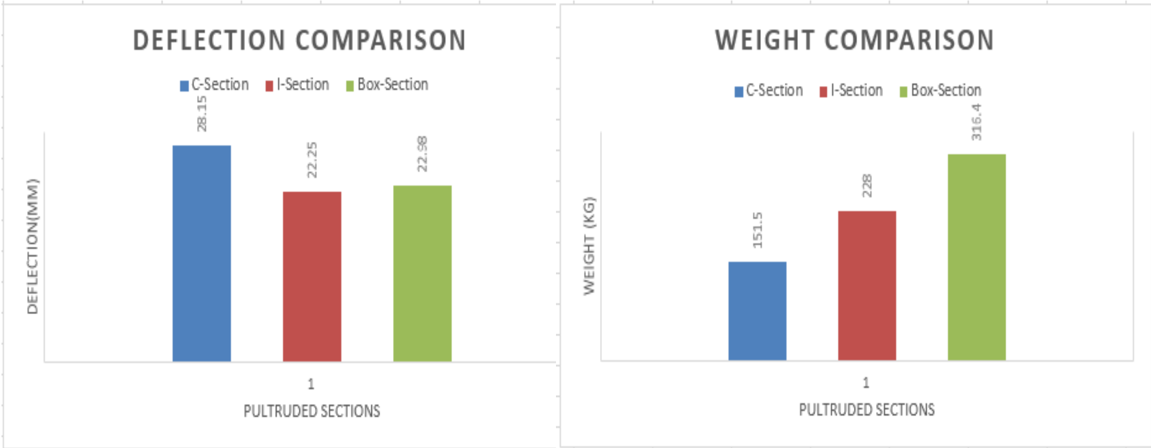
(a) Moment Capacity Comparison



(b) Shear Capacity Comparison

Figure 5.14: Comparison of Moment and Shear Capacities for 20m span

The graphical representation of deflection and weight are shown in Figure 5.15



(a) comparison of deflection (b) comparison of weight

Figure 5.15: Comparison of deflection and weight for 20m span

5.2.2 Truss type Pedestrian Bridge

For the truss type pedestrian bridge the cross girders comparison with the different sections for various spans are shown below.

- **3m and 5m Span truss type pedestrian bridge**

Total 3 sections were considered for the cross girder. The sections considered for the cross girder are shown in Figure 5.16.

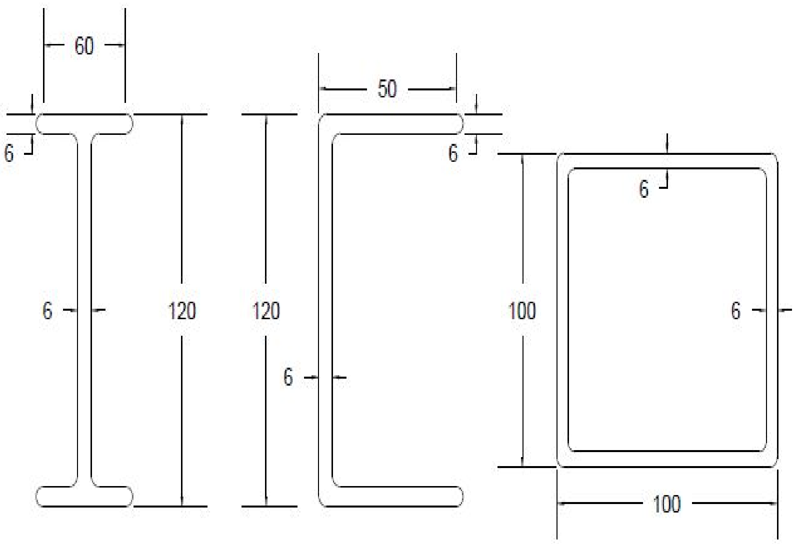


Figure 5.16: Sections Considered for 3m span Cross Girder

The geometric properties of the sections are shown in the Table 4.24.

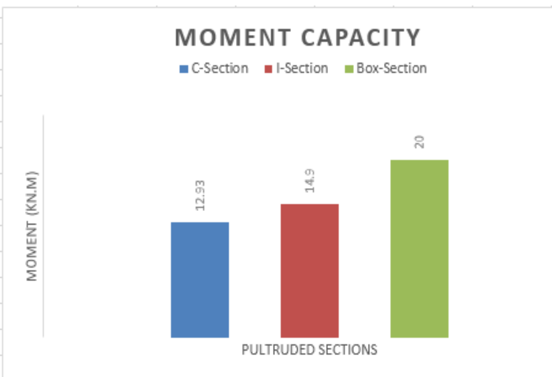
The comparison of the different parameters for the different sections are shown in the Table 5.9.

Table 5.9: Comparison of Sections

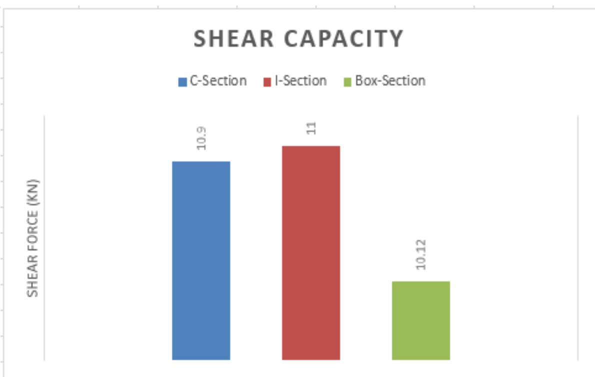
Parameters	**C-Section**	**I-Section**	**Box-Section**
Moment Capacity (kN.m)	12.93	14.9	20
Shear Capacity (kN)	10.9	11	10.12
Deflection (mm)	2.96	2.91	2.51
Weight (kg)	3.5	3.8	6.3

The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is same as I and C sections. The deflection of Box-section is same as C and I Sections. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in Figure 5.17



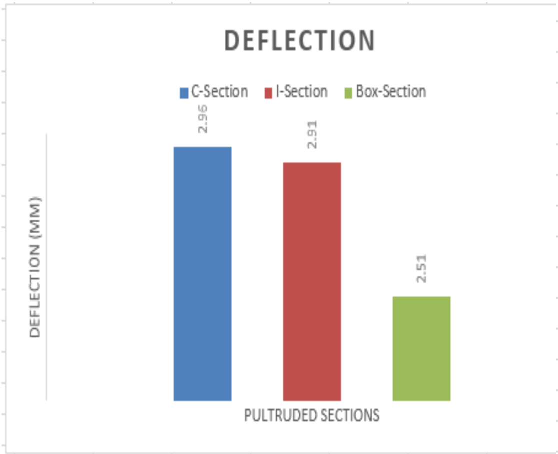
(a) Moment Capacity Comparison



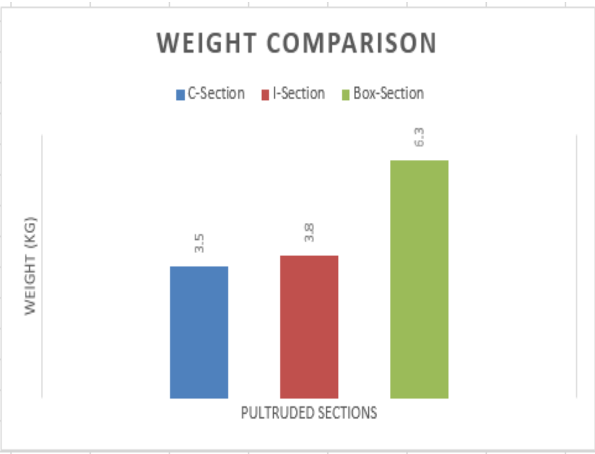
(b) Shear Capacity Comparison

Figure 5.17: Comparison of Moment and Shear Capacities for 3m and 5m spans

The graphical representation of deflection and weight are shown in Figure 5.18



(a) comparison of deflection



(b) comparison of weight

Figure 5.18: Comparison of deflection and weight for 3m and 5m spans

Top Chord member for 3m and 5m span

For the Design of Top chord member the Angle Section and Box-Section has been considered. The section selected for the Top chord member are shown in Figure 5.19.

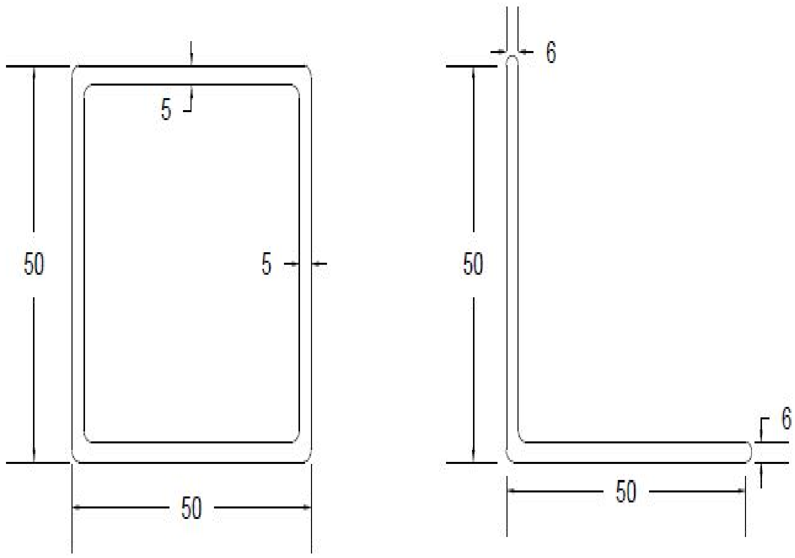


Figure 5.19: Sections Considered for Top Chord Member

The geometric properties of the sections are shown in Table 4.26.

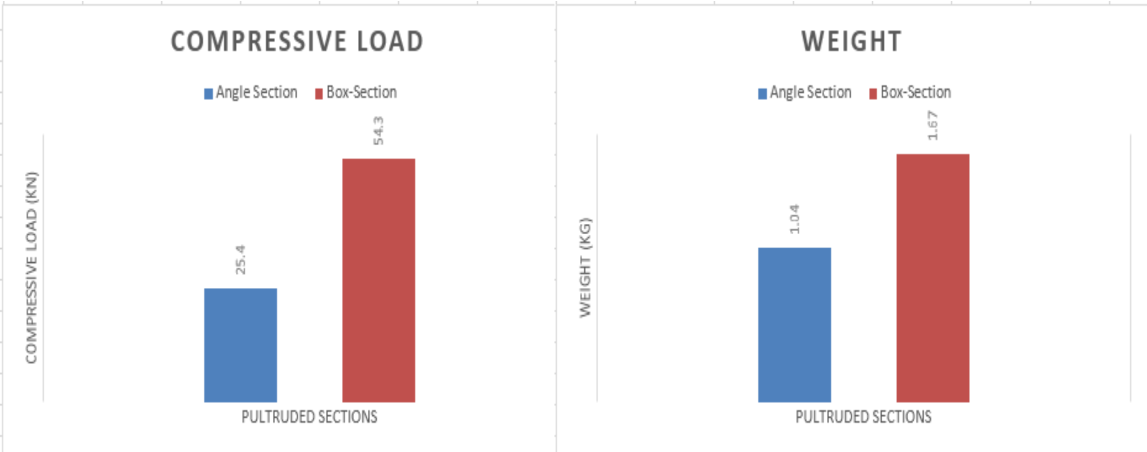
The comparison of the different parameters for the different sections are shown in Table 5.10

Table 5.10: Comparison of Sections

Parameters	**Angle-Section**	**Box-Section**
Compressive Load	25.4	54.3
Weight	1.04	1.67

The results shows that the axial load carrying capacity of the box section is higher than the angle section. There is not much difference in weight for both the sections so any section either of the angle or box sections can be used for top chord member.

The graphical representation of the comparison are shown in the Figure 5.20.



(a) compressive load comparison (b) comparison of weight

Figure 5.20: Comparison of compressive load and weight for 3m and 5m spans

Bottom Chord member for 3m and 5m spans

For the Design of Bottom chord member the Angle Section and Box-Section has been considered. The section selected for the Bottom chord member are shown in Figure 5.19. The geometric properties of the sections are shown in Table 4.26.

The comparison of the different parameters for the different sections are shown in Table 5.11

Table 5.11: Comparison of Sections

Parameters	**Angle-Section**	**Box-Section**
Tensile Load	112.8	180
Weight	1.04	1.67

The results shows that the tensile load carrying capacity of angle section is lower than the box section. There is not much difference in weight for both the sections so either of the sections can be used for bottom chord member.

The graphical representation for comparison of tensile load is shown in Figure 5.21.The comparison of weight is shown in Figure 5.16(b).

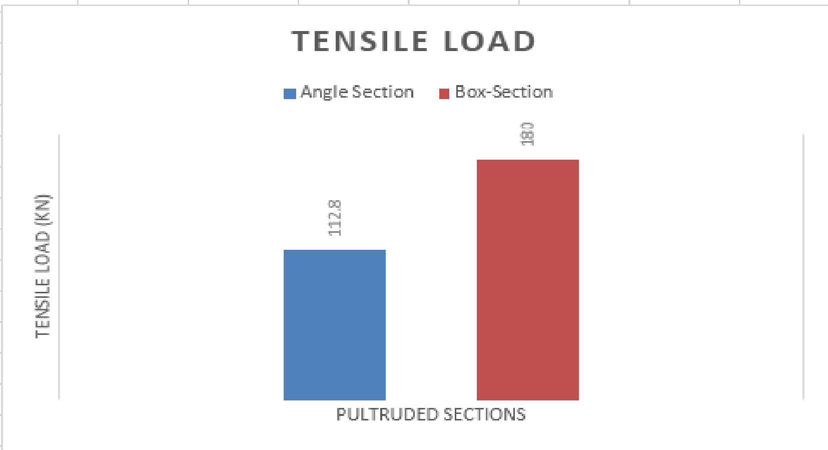


Figure 5.21: Tensile load comparison for 3m and 5m spans

Vertical member for 3m and 5m spans

For the Design of Vertical member the Angle Section and Box-Section has been considered.

The section selected for the Bottom chord member are shown in Figure 5.19.

The geometric properties of the sections are shown in Table 4.26.

The comparison of the different parameters for the different sections are shown in Table 5.12.

Table 5.12: Comparison for various Sections

Parameters	Angle-Section	Box-Section
Compressive Load	25.4	54.3
Tensile Load	112.6	180
Weight	1.04	1.67

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for vertical members.

The graphical representation for the comparison are shown in Figures 5.20(a and b) and 5.21.

Diagonal member for 3m and 5m spans

For the Design of Diagonal member the Angle Section and Box-Section has been considered. The section selected for the Bottom chord member are shown in Figure 5.19.

The geometric properties of the sections are shown in Table 4.26.

The comparison of the different parameters for the different sections are shown in Table 5.13.

Table 5.13: Comparison for various Sections

Parameters	Angle-Section	Box-Section
Compressive Load	25.4	54.3
Tensile Load	112.6	180
Weight	1.5	2.35

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for diagonal members.

The graphical comparison for the compressive load and tensile load are shown in figure 5.20(a) and 5.21 resp. The weight comparison is shown in Figure 5.22.

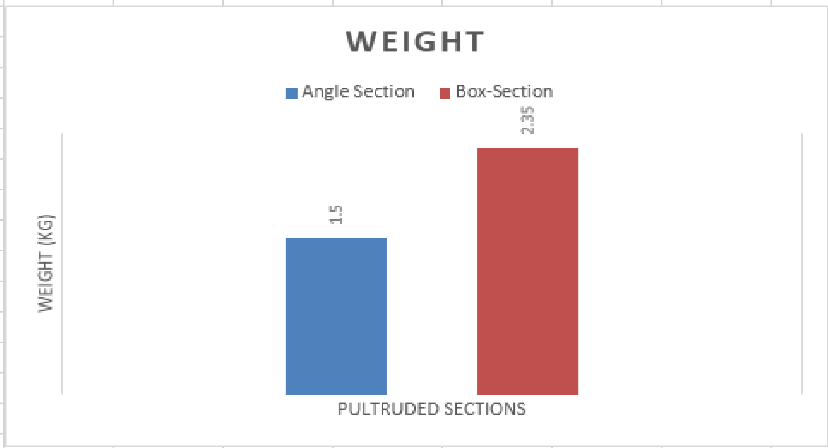


Figure 5.22: Comparison of weight for Diagonal Member

- **10m Span truss type pedestrian bridge**

Cross Girders for 10m span

Total 3 sections were considered for the cross girder. The sections considered for the cross girder are shown in Figure 5.16.

The geometric properties of the sections are shown in the Table 4.24.

The comparison of the different parameters for the different sections are shown in the Table 5.9.

The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is same as I and C sections. The deflection of Box-section is same as C and I Sections. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in Figure 5.17

The graphical representation of deflection and weight are shown in Figure 5.18

Top Chord member for 10m span

The sections considered for the top chord member are shown in Figure 5.23.

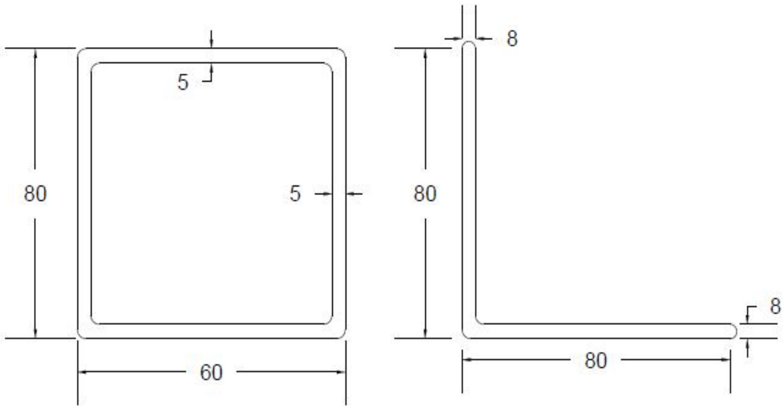


Figure 5.23: Sections considered for top chord member

The geometric properties of the sections are shown in Table 5.14.

Table 5.14: Geometric properties of the sections

Parameters	**Symbols**	**Units**	**Angle-Section**	**Box-Section**
Depth of Section	D	mm	80	80
Width of Section	B	mm	80	60
Thickness	t	mm	8	5
Cross-Section Area	A	mm^2	1216	1300
Moment of Inertia	I_{xx}	mm^4	729924.98	1412500
Section Modulus	W_{xx}	mm^3	12793.89	35312.5

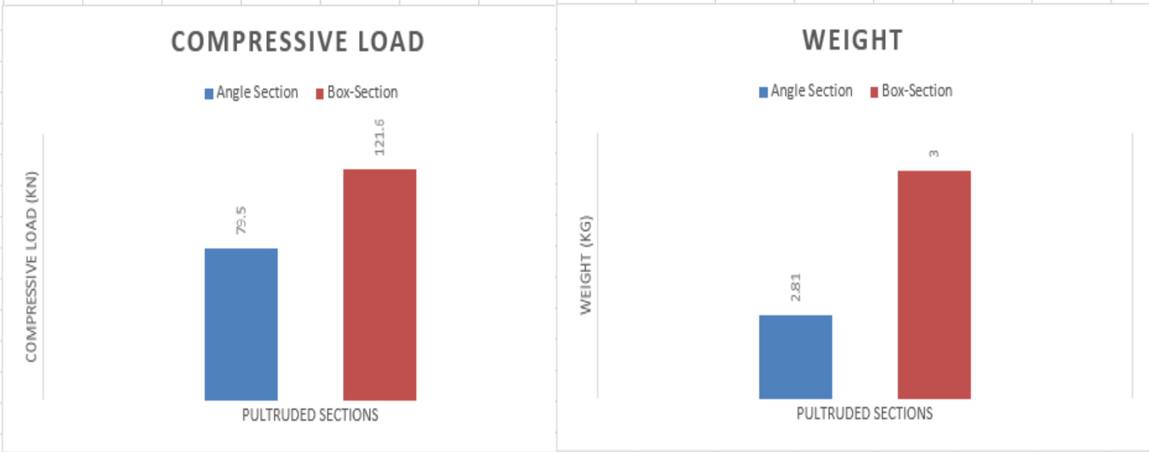
The comparison of the different parameters for the different sections are shown in Table 5.15

Table 5.15: Comparison of Sections

Parameters	**Angle-Section**	**Box-Section**
Compressive Load	79.5	121.6
Weight	2.81	3

The results shows that the axial load carrying capacity of the box section is higher than the angle section. There is not much difference in weight for both the sections so any section either of the angle or box sections can be used for top chord member.

The graphical representation of the comparison for load compressive load and weight are shown in the Figure 5.24.



(a) compressive load comparison (b) comparison of weight

Figure 5.24: Comparison of compressive load and weight for 10m span

Bottom Chord member for 10m span

The sections considered for the bottom chord member are shown in Figure 5.23.

The geometric properties of the sections are shown in Table 5.14.

The comparison of the different parameters for the different sections are shown in Table 5.16.

Table 5.16: Comparison of Sections

Parameters	**Angle-Section**	**Box-Section**
Tensile Load	260	243.2
Weight	2.81	3

The results shows that the tensile load carrying capacity of angle section is lower than the box section. There is not much difference in weight for both the sections so either of the sections can be used for bottom chord member.

The graphical representation of the comparison is shown in figure. For the weight comparison is already shown in Figure 5.18(b). The tensile load comparison is shown in Figure 5.25.

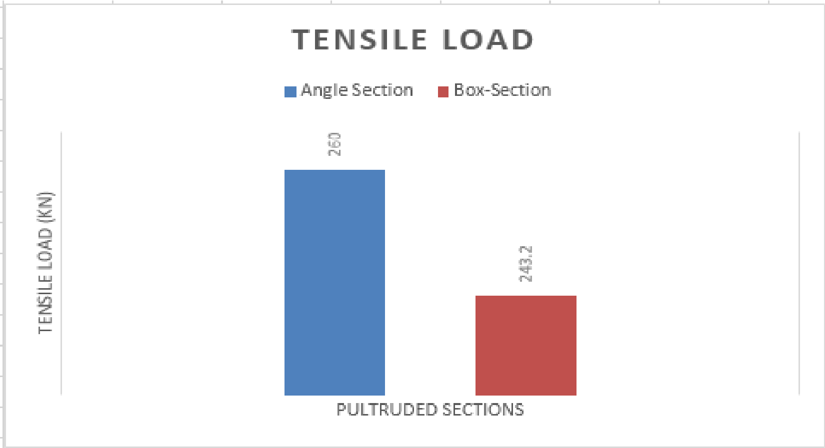


Figure 5.25: Tensile load comparison for 10m span

Vertical member for 10m span

For the Design of Vertical member the Angle Section and Box-Section has been considered. The section selected for the Bottom chord member are shown in Figure 5.19. The geometric properties of the sections are shown in Table 4.26. The comparison of the different parameters for the different sections are shown in Table 5.12.

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for vertical members.

The graphical representation for the comparison are shown in Figures 5.20(a and b) and 5.21.

Diagonal member for 10m span

For the Design of Vertical member the Angle Section and Box-Section has been considered.

The section selected for the Bottom chord member are shown in Figure 5.19.

The geometric properties of the sections are shown in Table 4.26.

The comparison of the different parameters for the different sections are shown in Table 5.17.

Table 5.17: Comparison for various Sections

Parameters	Angle-Section	Box-Section
Compressive Load	25.4	54.3
Tensile Load	112.6	180
Weight	1.7	2.7

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for diagonal members.

The graphical comparison for the compressive load and tensile load are shown in figure 5.20(a) and 5.21 resp.The weight comparison is shown in Figure 5.26.

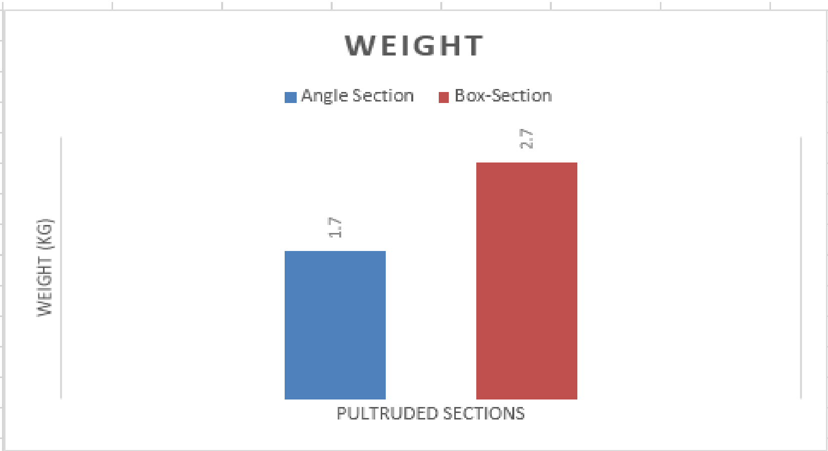


Figure 5.26: Comparison of weight for 10m span

- **15m Span truss type pedestrian bridge**

Cross Girders for 15m span

Total 3 sections were considered for the cross girder. The sections considered for the cross girder are shown in Figure 5.16. The geometric properties of the sections are shown in the Table 4.24. The comparison of the different parameters for the different sections are shown in the Table 5.9.

The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is same as I and C sections. The deflection of Box-section is same as C and I Sections. But the self weight of the box-section is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in figure 5.17. The graphical representation of deflection and weight are shown in Figure 5.18

Top Chord member for 15m span

The sections considered for the top chord member are shown in Figure 5.27.

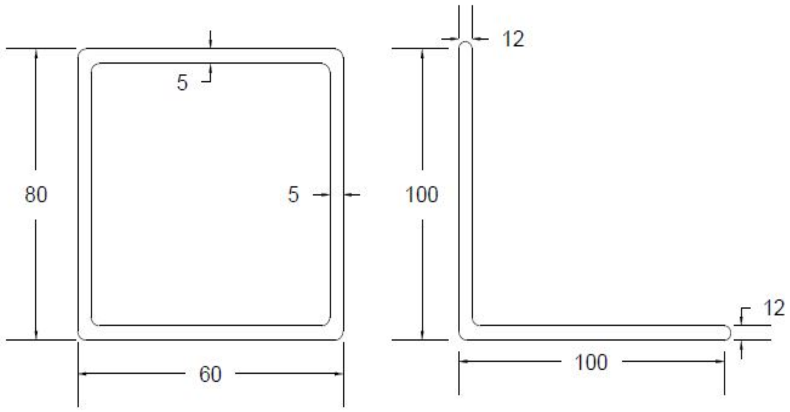


Figure 5.27: sections considered for the top chord member

The geometric properties of the sections are shown in Table 5.18.

Table 5.18: Geometric properties of the sections

Parameters	**Symbols**	**Units**	**Angle-Section**	**Box-Section**
Depth of Section	D	mm	100	80
Width of Section	B	mm	100	60
Thickness	t	mm	12	5
Cross-Section Area	A	mm^2	2256	1776
Moment of Inertia	I_{xx}	mm^4	2079126.05	3335872
Section Modulus	W_{xx}	mm^3	29451.15	66717.44

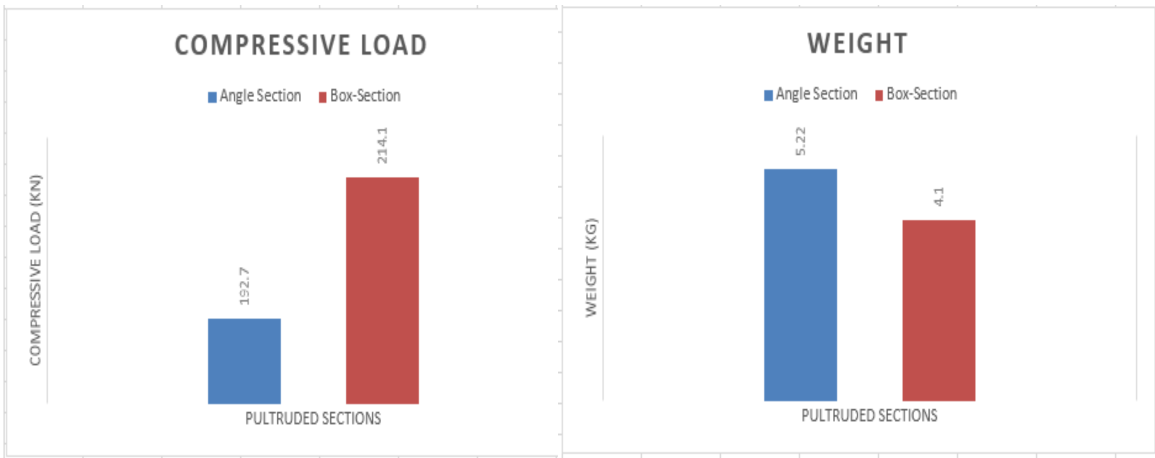
The comparison of the different parameters for the different sections are shown in Table 5.19

Table 5.19: Comparison of Sections

Parameters	Angle-Section	Box-Section
Compressive Load	192.7	214.1
Weight	5.22	4.1

The results shows that the axial load carrying capacity of the box section is higher than the angle section. There is not much difference in weight for both the sections so any section either of the angle or box sections can be used for top chord member.

The graphical representation of the comparison are shown in the Figure 5.28.



(a) compressive load comparison (b) comparison of weight

Figure 5.28: Comparison of compressive load and weight for 15m span

Bottom Chord member for 15m span

The sections considered for the bottom chord member are shown in Figure 5.23.

The geometric properties of the sections are shown in Table 5.14.

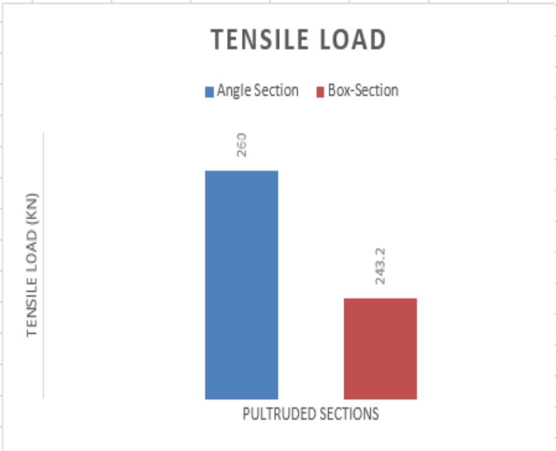
The comparison of the different parameters for the different sections are shown in Table 5.20.

Table 5.20: Comparison of Sections

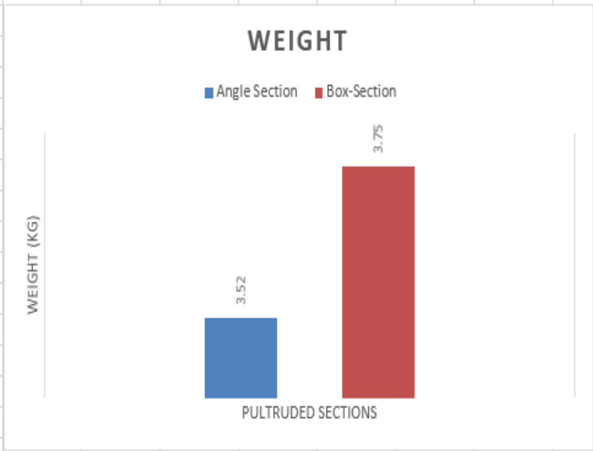
Parameters	Angle-Section	Box-Section
Tensile Load	260	243.2
Weight	3.52	3.75

The results shows that the tensile load carrying capacity of angle section is lower than the box section. There is not much difference in weight for both the sections so either of the sections can be used for bottom chord member.

The graphical representation of the comparison is shown in Figure 5.29.



(a) tensile load comparison



(b) comparison of weight

Figure 5.29: Comparison of Tensile load and weight for 15m span

Vertical member for 15m span

The sections considered for the vertical member are shown in Figure 5.23.

The geometric properties of the sections are shown in Table 5.14.The comparison of the different parameters for the different sections are shown in Table 5.16.

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for vertical members.

The graphical representation for the comparison are shown in Figures 5.18 ,5.19 and 5.20.

Diagonal member for 15m span

The sections considered for the diagonal member are shown in Figure 5.23.

The geometric properties of the sections are shown in table 5.14. The comparison of the different parameters for the different sections are shown in Table 5.21.

Table 5.21: Comparison for various Sections

Parameters	Angle-Section	Box-Section
Compressive Load	79.5	121.6
Tensile Load	260	243.2
Weight	4.5	4.8

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for diagonal members.
The graphical comparison for the compressive load and tensile load are shown in Figures 5.18(a) and 5.20 resp. The weight is shown in Figure 5.30.

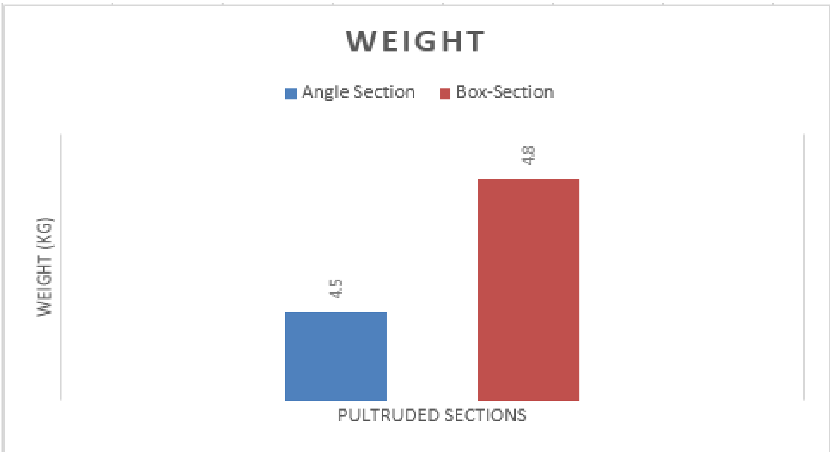


Figure 5.30: Comparison of weight for 15m span

- **20m Span truss type pedestrian bridge**

Cross Girders for 20m span

Total 3 sections were considered for the cross girder. The sections considered for the cross girder are shown in Figure 5.16.The geometric properties of the sections are shown in the Table 4.24. The comparison of the different parameters for the different sections are shown in the Table 5.9.
The results shows that the Box-Section has high moment carrying capacity than I and C sections. While the shear capacity of the box-section is same as I and C sections. The deflection of Box-section is same as C and I Sections. But the self weight of the box-section

is more than I and C sections so the weight of overall structure will increase in case of box-section. And the cost of Box-section is really high than the I and C sections. So for the economic section C-section turns out to be the best while for the high load carrying capacity Box-Section turns out to be the best. And the I-section is the intermediate sections.

The graphical representation of moment and shear capacities are shown in figure 5.17. The graphical representation of deflection and weight are shown in Figure 5.18.

Top Chord member for 20m span

The sections considered for the top chord member are shown in figure 5.31.

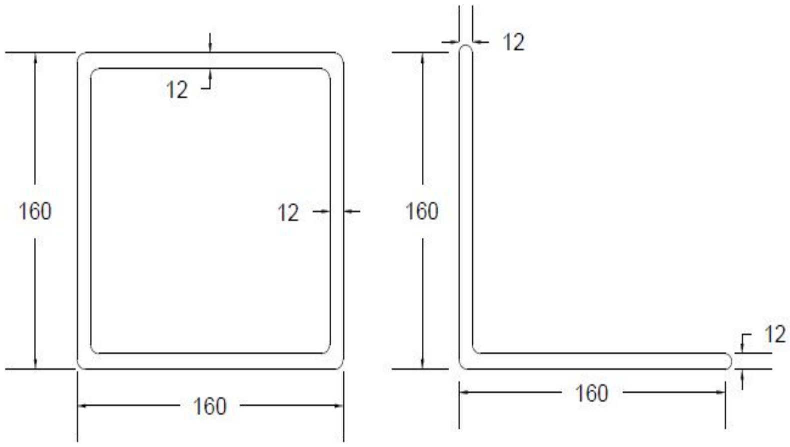


Figure 5.31: sections considered for the top chord member

The geometric properties of the sections are shown in Table 5.22.

Table 5.22: Geometric properties of the sections

Parameters	**Symbols**	**Units**	**Angle-Section**	**Box-Section**
Depth of Section	D	mm	160	160
Width of Section	B	mm	160	160
Thickness	t	mm	12	8
Cross-Section Area	A	mm^2	3696	4864
Moment of Inertia	I_{xx}	mm^4	9077760.82	18781525.33
Section Modulus	W_{xx}	mm^3	78555.58	234769.0667

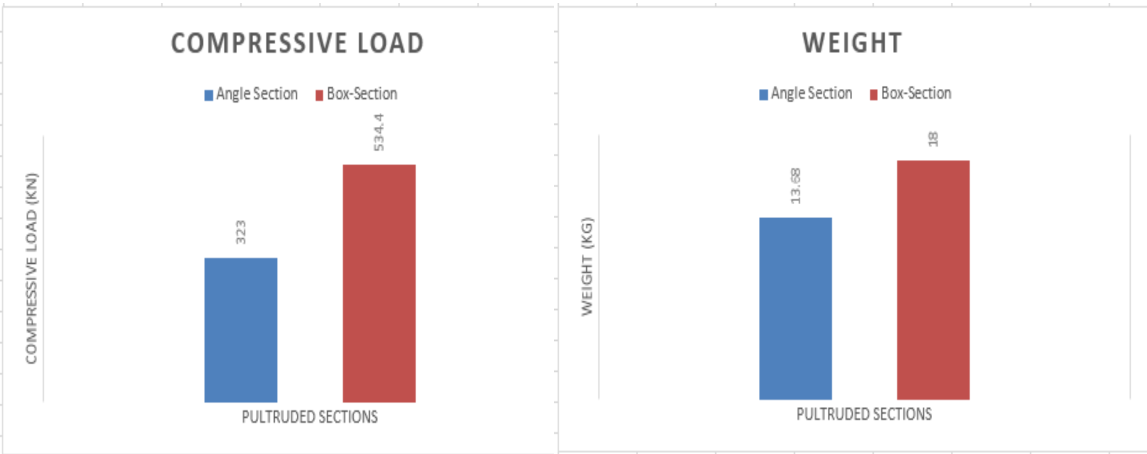
The comparison of the different parameters for the different sections are shown in Table 5.23.

Table 5.23: Comparison of Sections

Parameters	Angle-Section	Box-Section
Compressive Load	323	534.4
Weight	13.68	18

The results shows that the axial load carrying capacity of the box section is higher than the angle section. There is not much difference in weight for both the sections so any section either of the angle or box sections can be used for top chord member.

The graphical representation of the comparison are shown in the Figure 5.32.



(a) compressive load comparison (b) comparison of weight

Figure 5.32: Comparison of compressive load and weight for 20m span

Bottom Chord member for 20m span

The sections considered for the bottom chord member are shown in figure 5.31.

The geometric properties of the sections are shown in Table **??**.

The comparison of the different parameters for the different sections are shown in Table 5.24.

Table 5.24: Comparison of Sections

Parameters	Angle-Section	Box-Section
Tensile Load	739.2	972.8
Weight	13.68	18

The results shows that the tensile load carrying capacity of angle section is lower than the box section. There is not much difference in weight for both the sections so either of the sections can be used for bottom chord member.

The comparison for the weight is shown in Figure 5.26(b).The tensile load comparison for different sections for 15m span is shown in Figure 5.33.

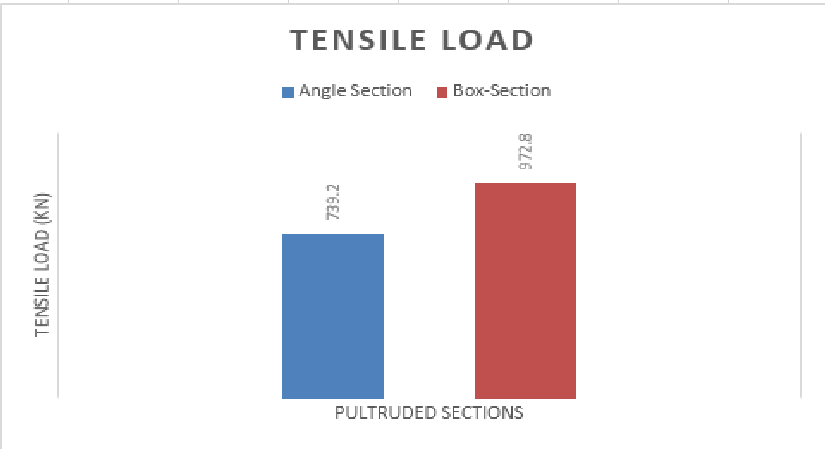


Figure 5.33: Tensile load comparison

Vertical member for 20m span

The sections considered for the vertical member are shown in figure 5.23.

The geometric properties of the sections are shown in Table 5.14. The comparison of the different parameters for the different sections are shown in Table 5.16.

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for vertical members.

The graphical representation for the comparison are shown in Figures 5.18 ,5.19 and 5.20.

Diagonal member for 20m span

The sections considered for the diagonal member are shown in figure 5.23.

The comparison of the different parameters for the different sections are shown in Table 5.25.

Table 5.25: Comparison for various Sections

Parameters	Angle-Section	Box-Section
Compressive Load	79.5	121.6
Tensile Load	260	243.2
Weight	6.3	6.72

The results shows that the angle section has lower axial load carrying capacity then the box section. The difference in weight for angle and box sections are not much so either sections can be used for diagonal members.

The graphical comparison for the compressive load and tensile load are shown in figure 5.18(a) and 5.20 resp. The weight comparison is shown in Figure 5.28.

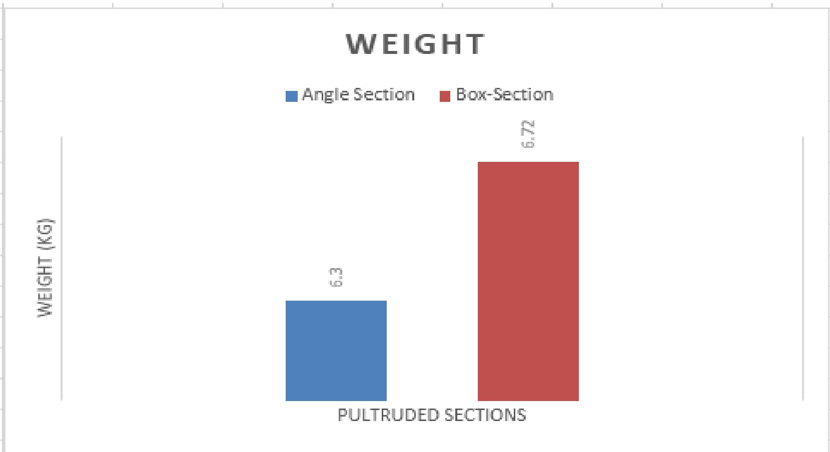


Figure 5.34: Comparison of Weight

5.3 Comparison of steel and pultruded sections

In this section the steel sections and pultruded sections are compared. The comparison is done by taking moment as constant for the beam type pedestrian bridge and comparing shear force, deflection, weight and cost. Similarly for the truss type pedestrian bridge the axial load is made constant and comparing weight and cost.

5.3.1 Beam type Pedestrian Bridge

For the beam type pedestrian bridge the moment of the section is kept constant and different parameters are compared.

- **3m span Beam type pedestrian bridge**

The sections used for the girder for 3m span is shown in Figure 5.35.

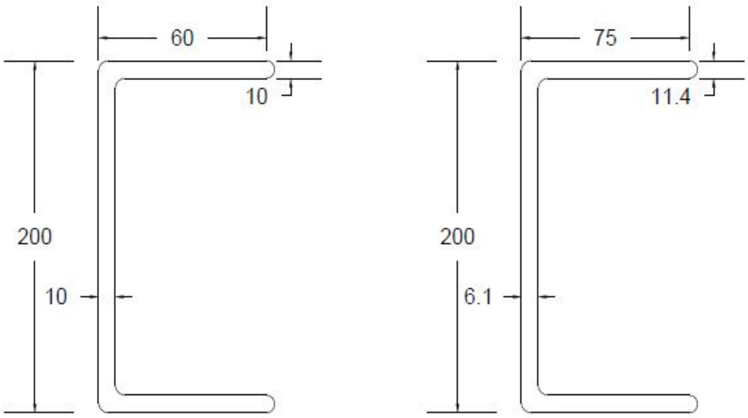


Figure 5.35: Sections used for 3m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.26.

Table 5.26: Comparison of steel and pultruded C-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		200×60×10	**ISMC 200**
Moment Capacity	kN.m	47.1	48.6
Shear Capacity	kN	29.8	96.2
Deflection	mm	7.03	1.1
Weight	kg	16.65	66.3

The comparison shows that by making moment as constant the shear capacity of pultruded section is less than steel sections. Similarly the deflection of pultruded section is more than steel sections but the self weight of pultruded section is significantly less than steel section and because of that the weight of the structure can be reduced. The graphical representation for moment capacity and shear capacity are shown in Figure 5.36.

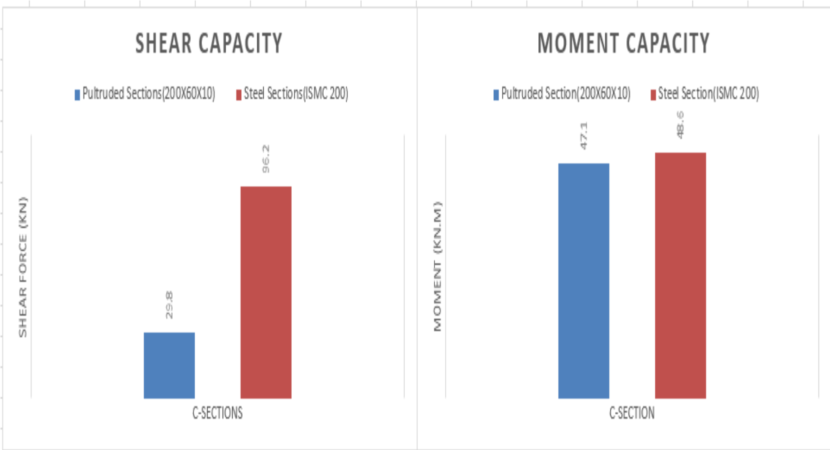


Figure 5.36: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.58.

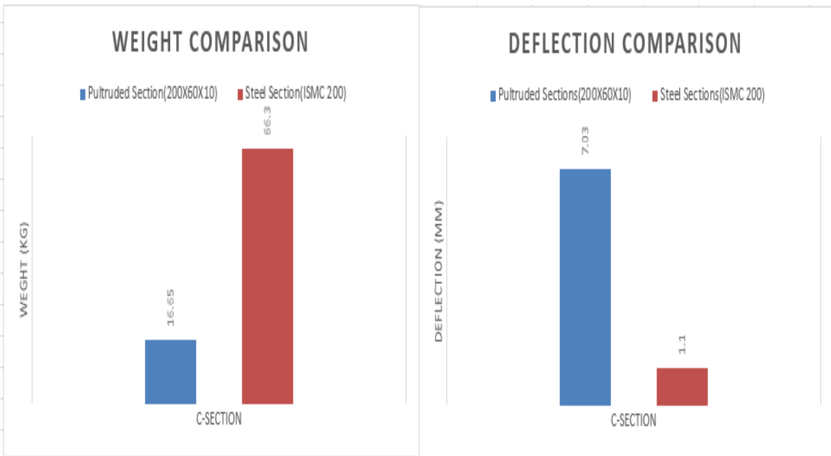


Figure 5.37: Comparison of weight and deflection for 3m span

Simiarly considering I-Section instead of C-section:

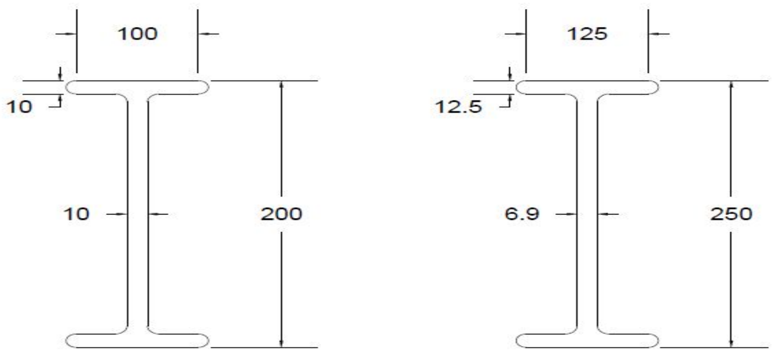


Figure 5.38: Sections used for 3m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.27.

Table 5.27: Comparison of steel and pultruded I-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		200×100×10	**ISMB 250**
Moment Capacity	kN.m	108.94	109.62
Shear Capacity	kN	30	135.97
Deflection	mm	4.86	0.4
Weight	kg	21.09	111.9

The result obtained are same as C-section that there is considerable saving in weight. The graphical representation for moment capacity and shear capacity are shown in Figure 5.39.

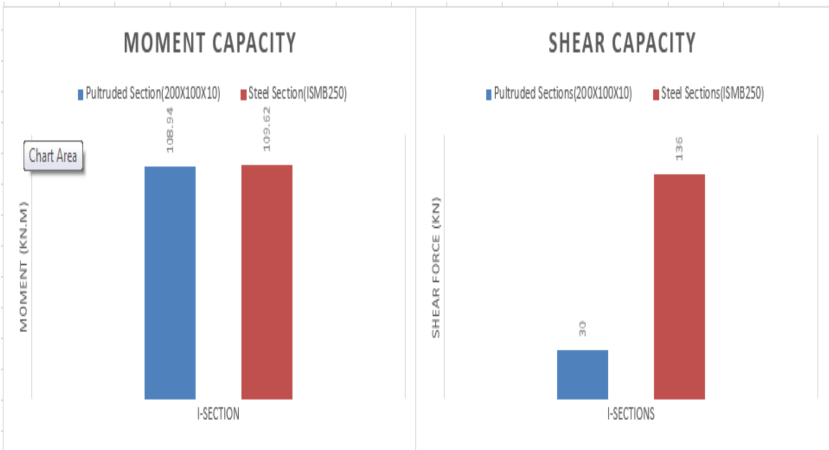


Figure 5.39: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.40.

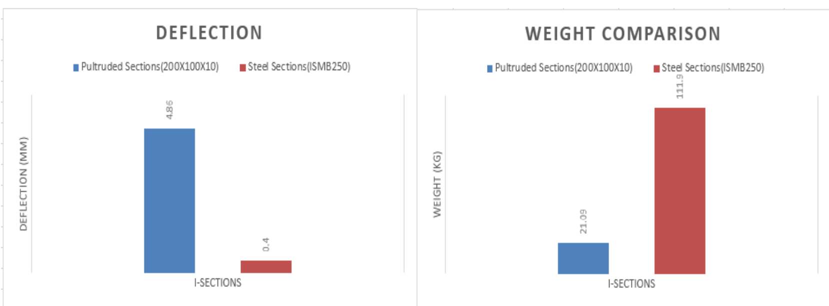


Figure 5.40: Comparison of weight and deflection for 3m span

- **5m span Beam type pedestrian bridge**

The sections used for the girder for 5m span is shown in Figure 5.41.

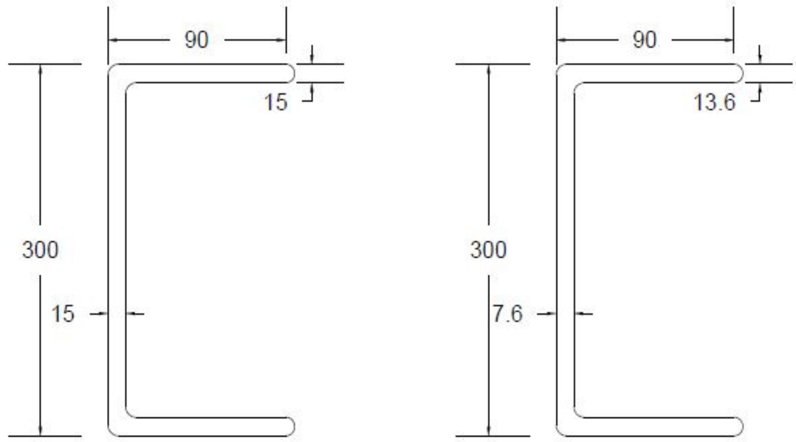


Figure 5.41: Sections used for 5m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.28.

Table 5.28: Comparison of steel and pultruded I-Section-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		300×90×15	**ISMC 300**
Moment Capacity	kN.m	106.02	113.3
Shear Capacity	kN	67.16	179.72
Deflection	mm	10.06	2.3
Weight	kg	62.5	179

The comparison shows that by making moment as constant the shear capacity of pultruded section is less than steel sections. Similarly the deflection of pultruded section is more than steel sections but the self weight of pultruded section is significantly less than steel section and because of that the weight of the structure can be reduced. The cost of pultruded section is also less than steel sections so which advantage in saving of weight the cost can also be reduced.
The graphical representation for moment capacity and shear capacity are shown in Figure 5.42.

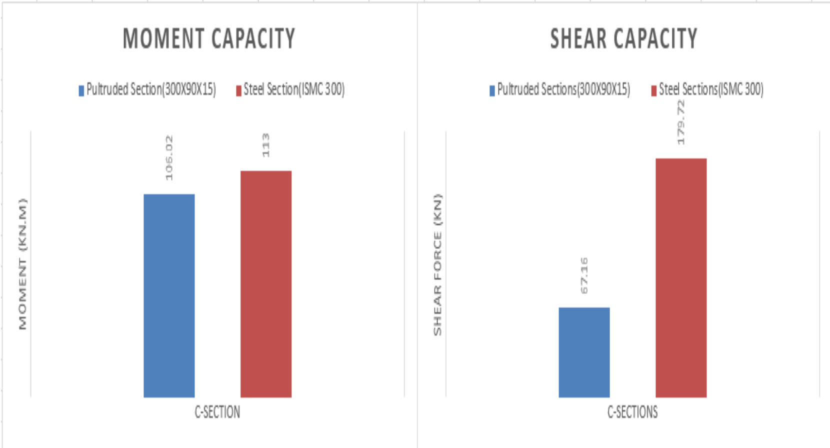


Figure 5.42: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.43.

Figure 5.43: Comparison of weight and deflection for 3m span

Simiarly considering I-Section instead of C-section:

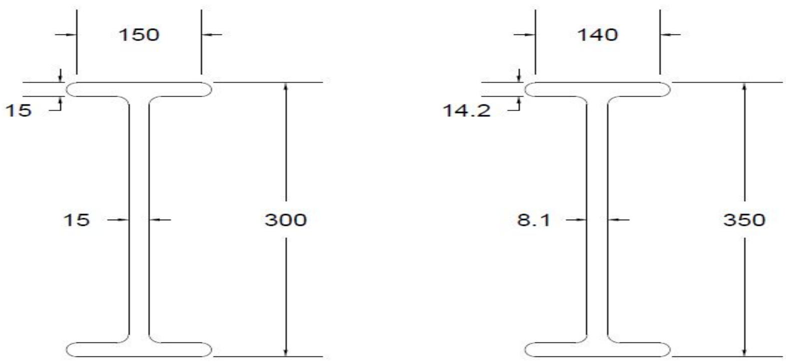


Figure 5.44: Sections used for 5m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.29.

Table 5.29: Comparison of steel and pultruded I-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		300×150×15	**ISMB 350**
Moment Capacity	kN.m	232.6	210
Shear Capacity	kN	68	223.5
Deflection	mm	6.94	1.12
Weight	kg	79.1	262

The result obtained are same as C-section that there is considerable saving in weight and the cost can also be reduced.

The graphical representation for moment capacity and shear capacity are shown in Figure 5.45.

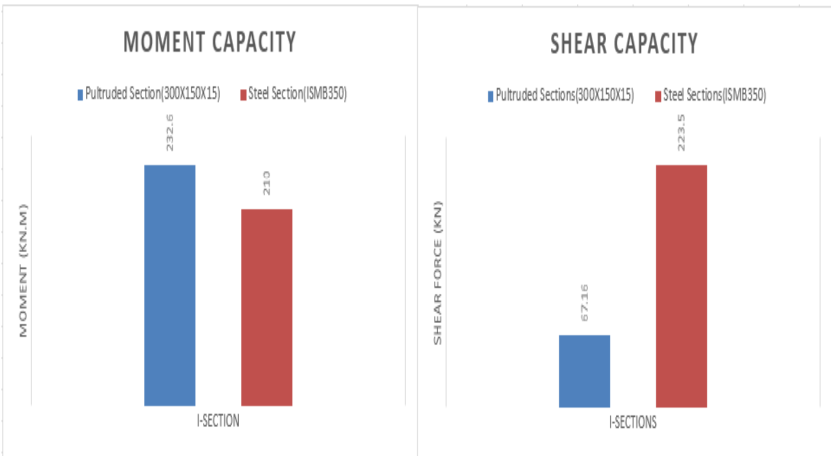


Figure 5.45: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.46.

Figure 5.46: Comparison of weight and deflection for 3m span

- **10m span Beam type pedestrian bridge**

For steel the highest C-section available is ISMC 400, so for 10m span the pultruded section is compared with ISMC 400.

The sections used for the girder for 10m span is shown in Figure 5.47.

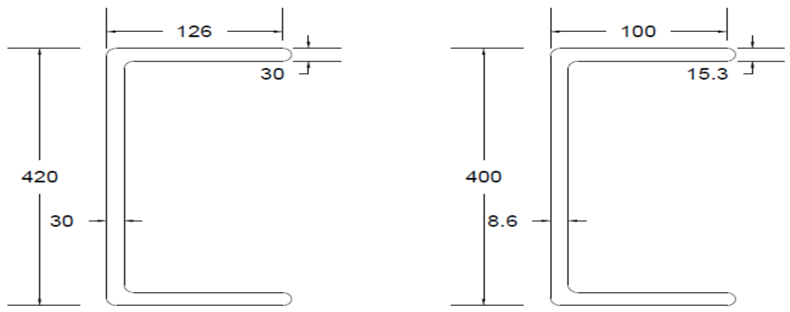


Figure 5.47: Sections used for 10m span girder

The geometric properties for both the sections are shown in Table **??**

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.30. But the highest steel section available is ISMC 400 so the moment constant is no possible.

The comparison shows that by making moment as constant the shear capacity of pultruded section is less than steel sections. Similarly the deflection of pultruded section is more than steel sections but the self weight of pultruded section is significantly less than steel section and because of that the weight of the structure can be reduced. The cost of

Table 5.30: Comparison of steel and pultruded I-Section-Section

Parameters	Units	Pultruded section	Steel Section
		420×126×30	**ISMC 400**
Moment Capacity	kN.m	577.81	201.4
Shear Capacity	kN	180.13	271.15
Deflection	mm	31.45	15.42
Weight	kg	340	494

pultruded section is also less than steel sections so which advantage in saving of weight the cost can also be reduced.

The graphical representation for moment capacity and shear capacity are shown in Figure 5.48.

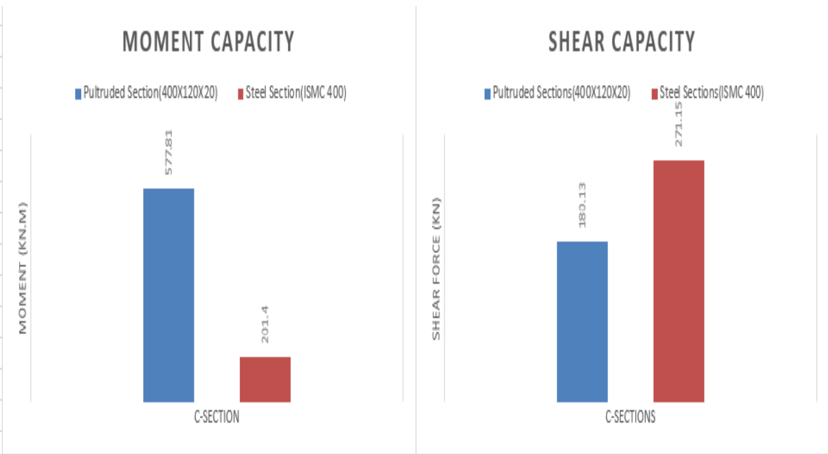


Figure 5.48: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.49.

Figure 5.49: Comparison of weight and deflection for 3m span

Simiarly considering I-Section instead of C-section:

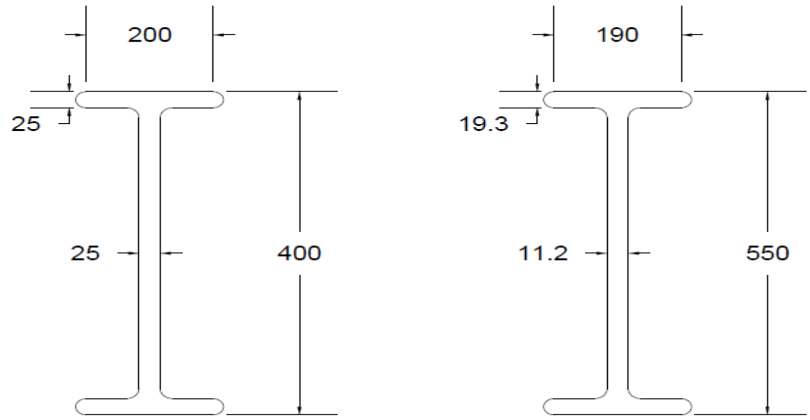


Figure 5.50: Sections used for 10m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.31.

Table 5.31: Comparison of steel and pultruded I-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		400×200×25	**ISMB 550**
Moment Capacity	kN.m	661.13	630.2
Shear Capacity	kN	146.4	485.55
Deflection	mm	28.96	3.77
Weight	kg	346.9	1037

The result obtained are same as C-section that there is considerable saving in weight. The graphical representation for moment capacity and shear capacity are shown in Figure 5.51.

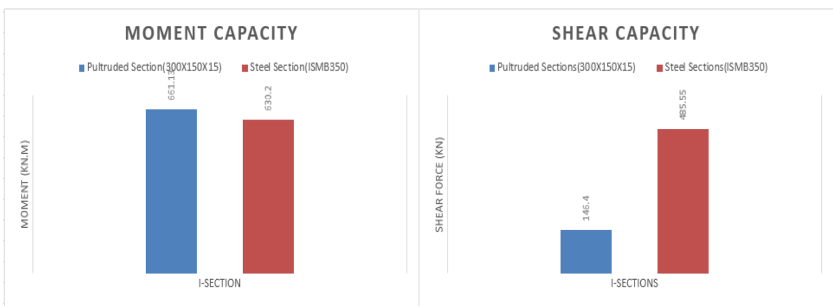


Figure 5.51: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.52.

Figure 5.52: Comparison of weight and deflection for 3m span

- **15m span Beam type pedestrian bridge**

For 15m span the girder is divided in two spans i.e. 7.5m. So for 15m span the comparison of 7.5m girder is considered.

The sections used for the girder for 15m span is shown in Figure 5.53.

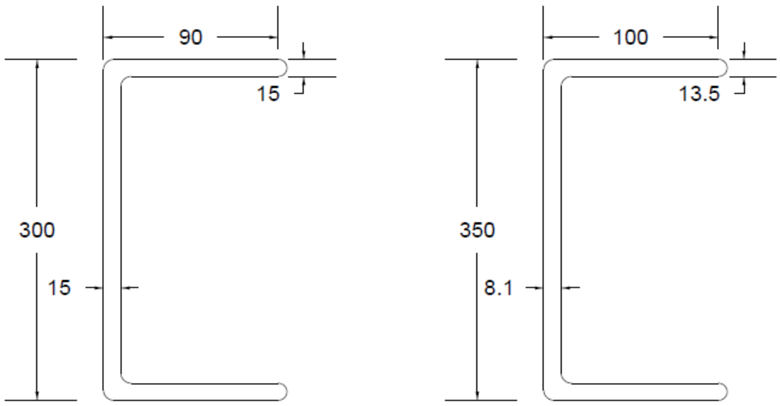


Figure 5.53: Sections used for 10m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.32.

Table 5.32: Comparison of steel and pultruded I-Section-Section

Parameters	Units	Pultruded section	Steel Section
		300×900×15	**ISMC 350**
Moment Capacity	kN.m	159.25	152.72
Shear Capacity	kN	67.42	223.46
Deflection	mm	21.17	7.35
Weight	kg	93.75	315.75

The comparison shows that by making moment as constant the shear capacity of pultruded section is less than steel sections. Similarly the deflection of pultruded section is more than steel sections but the self weight of pultruded section is significantly less than steel section and because of that the weight of the structure can be reduced. The cost of pultruded section is also less than steel sections so which advantage in saving of weight the cost can also be reduced.

The graphical representation for moment capacity and shear capacity are shown in Figure 5.54.

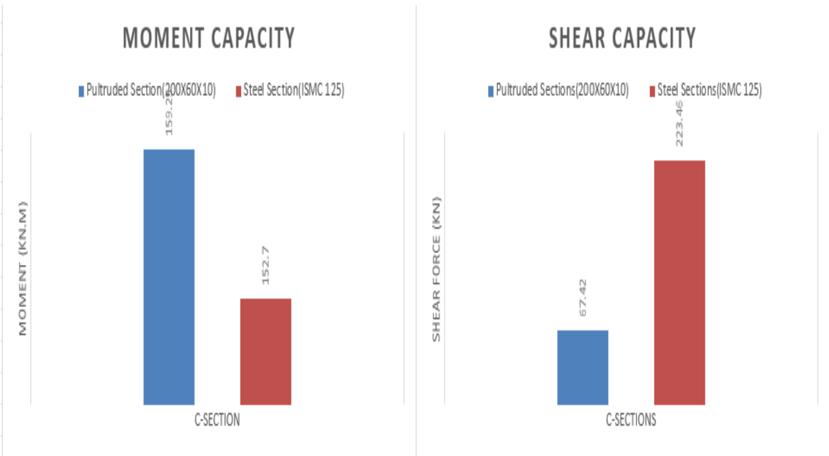


Figure 5.54: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.55.

Figure 5.55: Comparison of weight and deflection for 3m span

Simiarly considering I-Section instead of C-section:

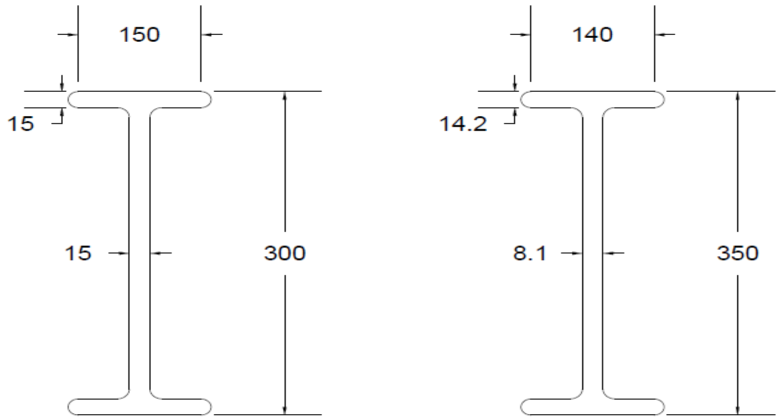


Figure 5.56: Sections used for 10m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.33.

Table 5.33: Comparison of steel and pultruded I-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		300×150×15	**ISMB 350**
Moment Capacity	kN.m	232.5	208
Shear Capacity	kN	68	223.45
Deflection	mm	14.63	5.7
Weight	kg	118.88	393

The result obtained are same as C-section that there is considerable saving in weight and the cost can also be reduced.

The graphical representation for moment capacity and shear capacity are shown in Figure 5.57.

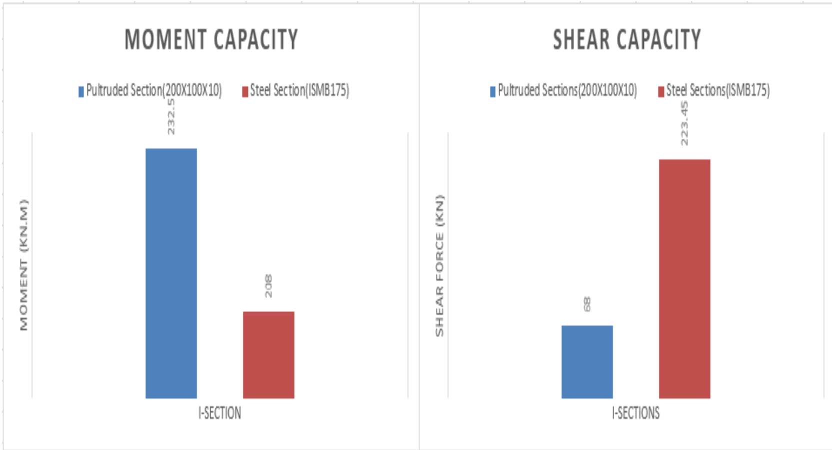


Figure 5.57: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure **??**.

Figure 5.58: Comparison of weight and deflection for 3m span

- **20m span Beam type pedestrian bridge**

For 20m span the girder is divided in two spans i.e. 10m. So for 20m span the comparison of 10m girder is considered.

The sections used for the girder for 20m span is shown in Figure 5.59.

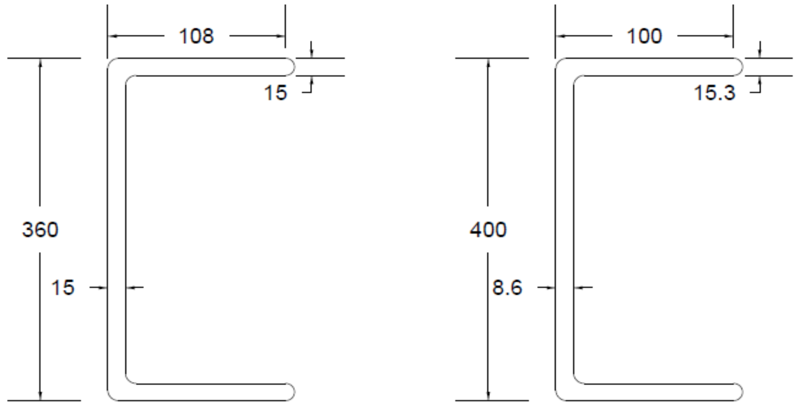


Figure 5.59: Sections used for 10m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.34.

Table 5.34: Comparison of steel and pultruded I-Section-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		360×108×15	**ISMC 400**
Moment Capacity	kN.m	235.64	201.4
Shear Capacity	kN	82.18	271.15
Deflection	mm	28.15	15.42
Weight	kg	151.5	494

The comparison shows that by making moment as constant the shear capacity of pultruded section is less than steel sections. Similarly the deflection of pultruded section is more than steel sections but the self weight of pultruded section is significantly less than steel section and because of that the weight of the structure can be reduced. The cost of pultruded section is also less than steel sections so which advantage in saving of weight the cost can also be reduced.

The graphical representation for moment capacity and shear capacity are shown in Figure 5.60.

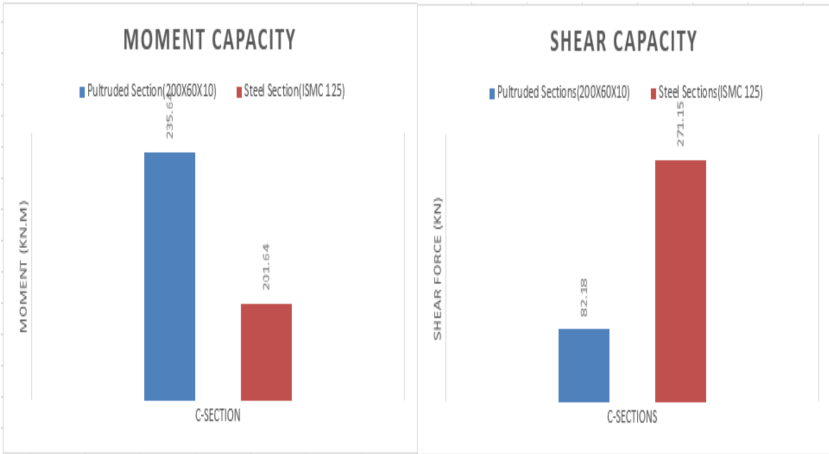


Figure 5.60: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.61.

Figure 5.61: Comparison of weight and deflection for 3m span

Simiarly considering I-Section instead of C-section:

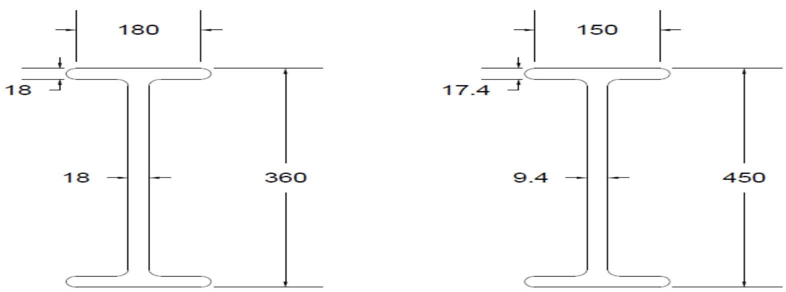


Figure 5.62: Sections used for 10m span girder

The moment capacity of the sections are kept constant and the comparison of the different parameters are studied. The comparison are shown in the Table 5.35.

Table 5.35: Comparison of steel and pultruded I-Section

Parameters	**Units**	**Pultruded section**	**Steel Section**
		360×180×18	**ISMB 450**
Moment Capacity	kN.m	400.95	360.7
Shear Capacity	kN	97.6	333.43
Deflection	mm	22.25	8.1
Weight	kg	228	724

The result obtained are same as C-section that there is considerable saving in weight and the cost can also be reduced.

The graphical representation for moment capacity and shear capacity are shown in Figure 5.63.

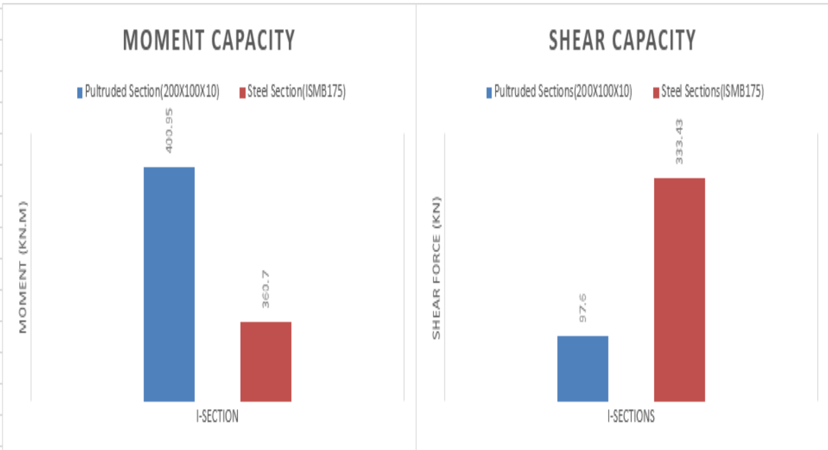


Figure 5.63: Comparison of Moment and Shear capacity for 3m span

The graphical representation for weight and deflection are shown in Figure 5.64.

Figure 5.64: Comparison of weight and deflection for 3m span

5.3.2 Truss Type Pedestrian Bridge

For the truss type pedestrian bridge, the axial force for the top chord, bottom chord, vertical and diagonal member are kept constant and for the cross girder the moment are kept constant.

- **3m and 5m spans truss type pedestrian bridge**

Cross Girder

For the cross girder the moment is kept constant and the different parameters are compared.

For cross girders the sections considered are shown in Figure 5.65.

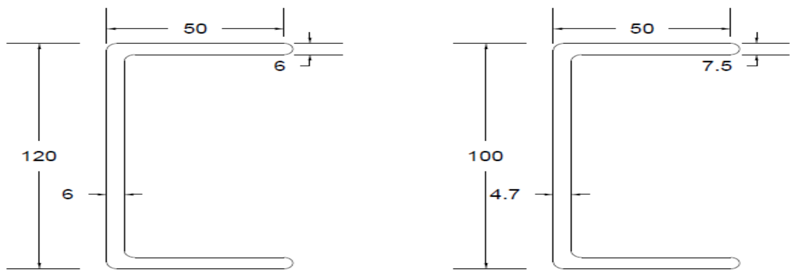


Figure 5.65: Sections considered for cross girder

For the cross girders the moment capacity is kept constant and the different parameters are compared. The comparison of different parameters are shown in Table 5.36

Table 5.36: Comparison of Different parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		120×500×6	**ISMC 100**
Moment	kN.m	12.93	10
Shear Force	kN	10.9	37.1
Deflection	mm	2.96	0.76
Weight	kg	3.5	13.8

The results shows that by taking moment constant the pultruded section has less shear capacity than steel section and the deflection of pultruded section is more than steel section but there is a considerable saving in weight and the cost of pultruded section is also less than steel section, so the overall cost of the structure can be reduced if pultruded section is used instead of steel section.

Similarly considering I-section instead of C-section.

For cross girders the sections considered are shown in Figure 5.66.

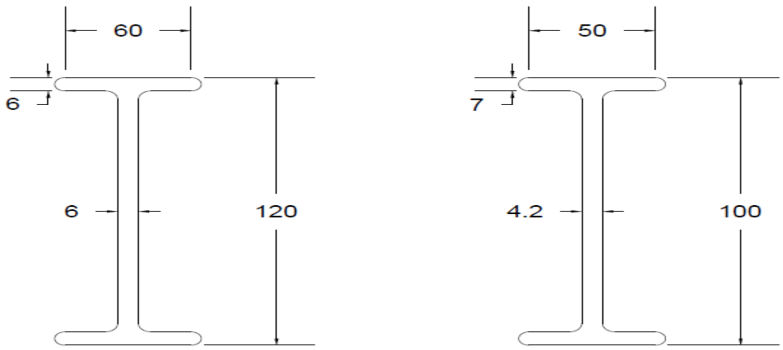


Figure 5.66: Sections considered for cross girder

For the cross girders the moment capacity is kept constant and the different parameters are compared.The comparison of different parameters are shown in Table 5.37

Table 5.37: Comparison of Different parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		120×600×6	**ISMB 100**
Moment	kN.m	14.9	13.75
Shear Force	kN	11	31.53
Deflection	mm	2.91	0.6
Weight	kg	3.8	17.25

The result obtained are same as C-section.

Top Chord Member

For the Top chord member the axial compression force is kept constant and the different parameters are compared. The sections considered for top chord member are shown in Figure 5.67.

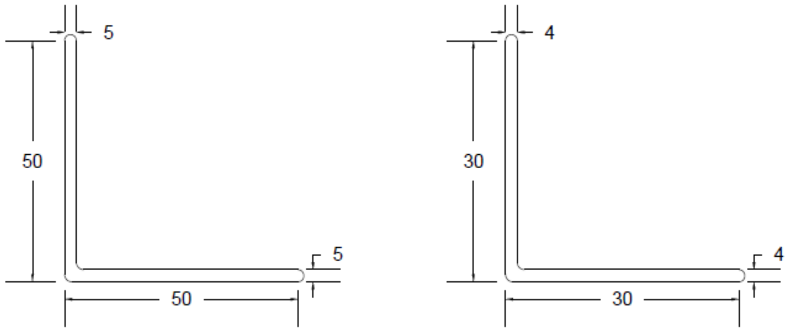


Figure 5.67: Sections used for 10m span girder

The comparison of the parameters are shown in Table 5.38.

Table 5.38: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		50×50×6	**30×30×4**
Compressive Load	kN	25.4	25.2
Weight	kg	1.04	1.8

The result shows that the pultruded section has less weight than steel sections so there is a saving in weight.

Bottom Chord member

For the bottom chord member the axial tensile force is kept constant and the different parameters are compared. The sections considered for bottom chord member are shown in Figure 5.68.

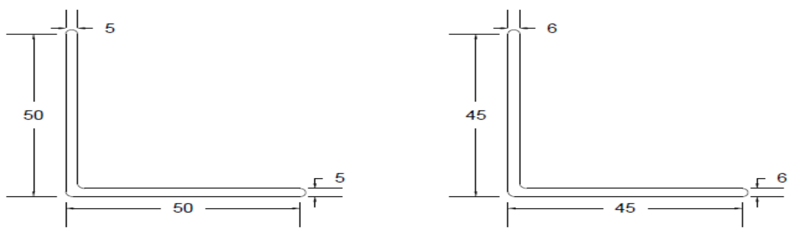


Figure 5.68: Sections used for 10m span girder

The comparison of the parameters are shown in Table 5.39.

Table 5.39: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		50×50×6	**45×45×6**
Tensile Load	kN	112.8	115.23
Weight	kg	1.04	4

The results shows that the weight of the pultruded section is less than the steel sections.

Vertical Member

For the vertical member the axial compressive force is kept constant and the different parameters are compared. The sections considered for vertical member are shown in Figure 5.67.

The comparison of the parameters are shown in Table 5.40.

Table 5.40: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		50×50×6	**30×30×}**
Compressive Load	kN	25.4	25.2
Tensile Load	kN	112.8	51.4
Weight	kg	1.04	1.8

The result shows that the tensile capacity of pultruded section is higher than steel section and the weight is less than steel section,so the overall weight of the structure can be reduced.

Diagonal Member

For the diagonal member the axial compressive force is kept constant and the different parameters are compared. The sections considered for diagonal member are shown in Figure 5.67.

The comparison of the parameters are shown in Table 5.41.

Table 5.41: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		50×50×6	**30×30×4**
Compressive Load	kN	25.4	25.2
Tensile Load	kN	112.8	51.4
Weight	kg	1.5	2.54

The result shows that the tensile capacity of pultruded section is higher than steel section and the weight is less than steel section,so the overall weight of the structure can be reduced.

- **10m span truss type pedestrian bridge**

Cross Girder

For the cross girder the moment is kept constant and the different parameters are compared.

For cross girders the sections considered are:
Pultruded section: 120×50×6
Steel section: ISMC 100
The comparison of geometric properties are shown in Table **??**
The comparison of different parameters are shown in Table 5.36.
Similarly considering I-section instead of C-section.
For cross girders the sections considered are:
Pultruded section: 120×60×6
Steel section: ISMB 100
The comparison of geometric properties are shown in Table **??**.
The comparison of different parameters are shown in Table 5.37.

Top chord member

For the Top chord member the axial compression force is kept constant and the different parameters are compared. The sections considered for top chord member are shown in Figure 5.69.

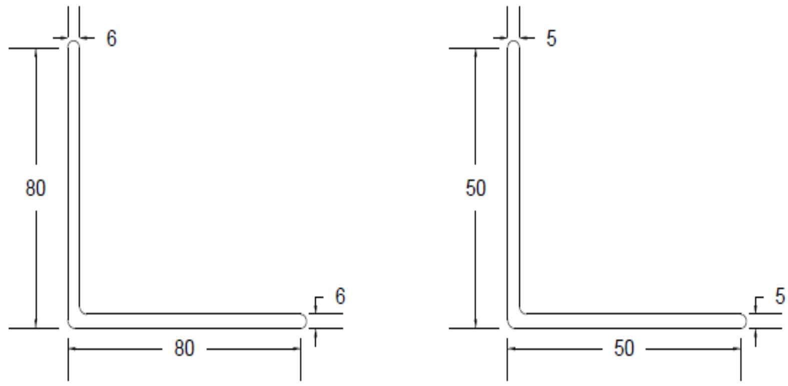


Figure 5.69: Sections used for 10m span girder

The comparison of the parameters are shown in Table 5.42.

Table 5.42: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		80×80×6	**50×50×5**
Compressive Load	kN	79.5	78.1
Weight	kg	2.81	4.75

The result shows that the pultruded section has less weight than steel sections though there is not much difference in cost but there is a saving in weight.

Bottom chord member

For the bottom chord member the axial tensile force is kept constant and the different parameters are compared. The sections considered for bottom chord member are shown in Figure 5.70.

The comparison of the parameters are shown in Table 5.43.

Table 5.43: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		80×80×8	**60×60×10**
Tensile Load	kN	260	250
Weight	kg	2.81	10.75

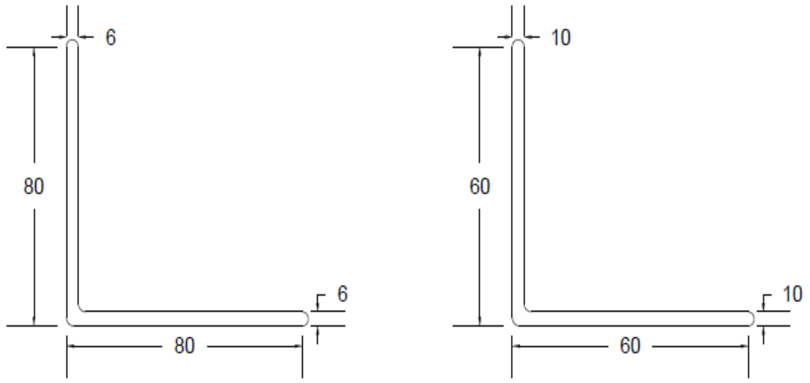


Figure 5.70: Sections used for 10m span girder

The result shows that the weight of the steel section is more than pultruded ection and the cost of steel section is also more than the pultruded section.So by using the pultruded section the weight of the structure as well as the cost can be reduced.

Vertical Member

For the vertical member the axial compressive force is kept constant and the different parameters are compared. The sections considered for vertical member are shown in Figure 5.67.

The comparison of the parameters are shown in Table 5.40.

Diagonal Member

For the diagonal member the axial compressive force is kept constant and the different parameters are compared. The sections considered for diagonal member are shown in Figure 5.67.

The comparison of the parameters are shown in Table 5.44.

Table 5.44: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		50×50×6	**30×30×4**
Compressive Load	kN	25.4	25.2
Tensile Load	kN	112.8	51.4
Weight	kg	1.7	2.88

The result shows that the tensile capacity of pultruded section is higher than steel section and the weight is less than steel section. Though there is not much difference in cost but by using pultruded section the overall weight of the structure can be reduced.

- **15m span truss type pedestrian bridge**

Cross Girder

For the cross girder the moment is kept constant and the different parameters are compared.

For cross girders the sections considered are:

Pultruded section: 120×50×6

Steel section: ISMC 100

The comparison of different parameters are shown in Table 5.36.

Similarly considering I-section instead of C-section.

For cross girders the sections considered are:

Pultruded section: 120×60×6

Steel section: ISMB 100

The comparison of different parameters are shown in Table 5.37.

Top chord member

For the Top chord member the axial compression force is kept constant and the different parameters are compared. The sections considered for top chord member are shown in Figure 5.71.

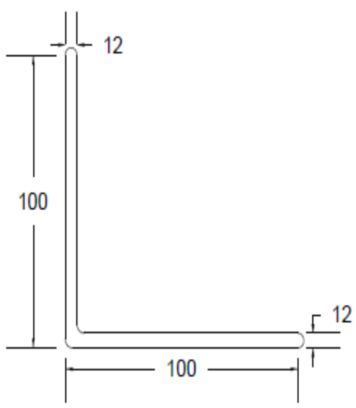


Figure 5.71: Sections used for 10m span girder

The comparison of the parameters are shown in Table 5.45.

Table 5.45: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		100×100×12	**70×70×8**
Compressive Load	kN	192.7	207.8
Weight	kg	5.22	10.4

The result shows that the pultruded section has less weight than steel sections though there is not much difference in cost but there is a saving in weight.

Bottom Chord member

For the bottom chord member the axial tensile force is kept constant and the different parameters are compared. The sections considered for bottom chord member are shown in Figure 5.70.

The comparison of the parameters are shown in Table 5.43.

Vertical member

For the vertical member the axial compressive force is kept constant and the different parameters are compared. The sections considered for vertical member are shown in Figure 5.69.

The comparison of the parameters are shown in Table 5.46.

Table 5.46: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		80×80×8	**50×50×5**
Compressive Load	kN	79.5	78.1
Tensile Load	kN	280	108.86
Weight	kg	2.81	4.75

The result shows that the tensile capacity of pultruded section is higher than steel section and the weight is less than steel section. Though there is not much difference in cost but by using pultruded section the overall weight of the structure can be reduced.

Diagonal Member

For the diagonal member the axial compressive force is kept constant and the different parameters are compared. The sections considered for diagonal member are shown in Figure 5.69.

The comparison of the parameters are shown in Table 5.47.

Table 5.47: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		80×80×8	**50×50×5**
Compressive Load	kN	79.5	78.1
Tensile Load	kN	280	108.86
Weight	kg	4.5	7.6

The result shows that the tensile capacity of pultruded section is higher than steel section and the weight is less than steel section. Though there is not much difference in cost but by using pultruded section the overall weight of the structure can be reduced.

- **20m spam truss type pedestrian bridge**

Cross Girder

For the cross girder the moment is kept constant and the different parameters are compared.

For cross girders the sections considered are:

Pultruded section: 120×50×6

Steel section: ISMC 100

The comparison of different parameters are shown in Table 5.36.

Similarly considering I-section instead of C-section.

For cross girders the sections considered are:

Pultruded section: 120×60×6

Steel section: ISMB 100

The comparison of different parameters are shown in Table 5.37.

Top chord member

For the Top chord member the axial compression force is kept constant and the different parameters are compared. The sections considered for top chord member are shown in Figure 5.72.

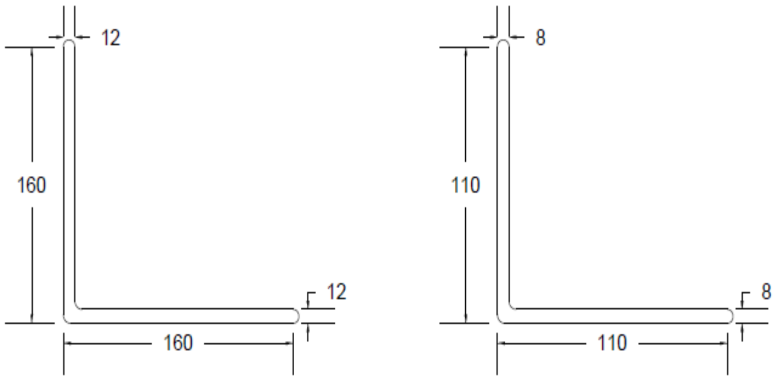


Figure 5.72: Sections used for 10m span girder

The comparison of the parameters are shown in Table 5.48.

Table 5.48: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		160×160×12	**110×110×8**
Compressive Load	kN	323	333.9
Weight	kg	13.7	26.8

The result shows that the pultruded section has less weight than steel sections though there is not much difference in cost but there is a saving in weight.

Bottom Chord member

For the bottom chord member the axial tensile force is kept constant and the different parameters are compared. The sections considered for bottom chord member are shown in Figure 5.73.

The comparison of the parameters are shown in Table 5.49.

The result shows that the weight of the steel section is more than pultruded ection and the cost of steel section is also more than the pultruded section.So by using the pultruded

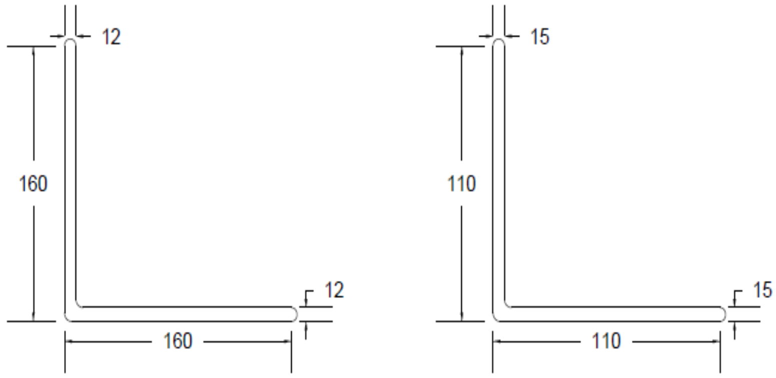


Figure 5.73: Sections used for 10m span girder

Table 5.49: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		160×160×12	**110×110×8**
Compressive Load	kN	740	700
Weight	kg	13.7	48.4

section the weight of the structure as well as the cost can be reduced.

Vertical Member

For the vertical member the axial compressive force is kept constant and the different parameters are compared. The sections considered for vertical member are shown in Figure 5.69.

The comparison of the parameters are shown in Table 5.46.

Diagonal Member

For the diagonal member the axial compressive force is kept constant and the different parameters are compared. The sections considered for diagonal member are shown in Figure 5.69.

The comparison of the parameters are shown in Table 5.50.

The result shows that the tensile capacity of pultruded section is higher than steel section and the weight is less than steel section, but by using pultruded section the overall weight of the structure can be reduced.

Table 5.50: Comparison of Different Parameters

Parameters	**Units**	**Pultruded section**	**Steel Section**
		80×80×8	**50×50×5**
Compressive Load	kN	79.5	78.1
Tensile Load	kN	280	108.86
Weight	kg	6.3	10.64

5.4 Summary

In this chapter the parametric study is carried out to determine the most economic section. The pulturded composites sections are compared with different sections to evaluate the optimimum section. The steel sections are compared with pultruded composites sections in terms of various parameters.

Chapter 6

Cost Estimation

6.1 General

In this chapter the cost estimation for the beam type and truss type pedestrian bridge is done for various spans. The estimation is done for the super structure only. The sub structure is not considered for the estimation.

6.2 Estimation of Beam Type Pedestrian Bridge

To compare the cost the weight of the material is necessary, so firstly the comparison of weight for pultruded and steel sections are shown first.

3m span Beam Type Pedestrian Bridge

Weight calculation for 3m span beam type pedestrian bridge is shown in Table 6.1. The weight is calculated for the sections only. The weight of the connections are not considered for the weight calculation and the weight for the superstructures are only considered. Weight of the substructure are not considered.

Table 6.1: Weight Calculation of Pultruded Sections for 3m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 3m			
Pultruded Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (200×60×10)	2	5.55	11.1
Box-Section (50×50×5)	28	1.67	46.76
Total			57.86

Weight calculation of steel sections for 3m span beam type pedestrian bridge are shown in Table 6.2.

Table 6.2: Weight Calculation of Steel Sections for 3m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 3m			
Steel Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (ISMC 200)	2	22.1	44.2
Box-Section (50×50×5)	28	4.12	115.36
Total			159.56

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

5m span Beam Type Pedestrian Bridge

Weight calculation for 5m span beam type pedestrian bridge is shown in Table 6.3.

Table 6.3: Weight Calculation of Pultruded Sections for 5m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 5m			
Pultruded Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (300×90×15)	2	12.5	25
Box-Section (50×50×5)	38	1.67	63.46
Total			88.46

Weight calculation of steel sections for 5m span beam type pedestrian bridge are shown in Table 6.4.

Table 6.4: Weight Calculation of Steel Sections for 5m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 5m			
Steel Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (ISMC 300)	2	35.8	71.6
Box-Section (50×50×5)	38	4.12	156.56
Total			228.16

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

10m span Beam Type Pedestrian Bridge

Weight calculation for 10m span beam type pedestrian bridge is shown in Table 6.5.

Table 6.5: Weight Calculation of Pultruded Sections for 10m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 10m			
Pultruded Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (420×126×30)	2	34	68
Box-Section (50×50×5)	78	1.67	130.26
Total			198.26

Weight calculation of steel sections for 10m span beam type pedestrian bridge are shown in Table 6.6.

Table 6.6: Weight Calculation of Steel Sections for 10m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 10m			
Steel Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (ISMC 400)	2	49.4	98.8
Box-Section (50×50×5)	78	4.12	321.36
Total			420.16

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

15m span Beam Type Pedestrian Bridge

Weight calculation for 15m span beam type pedestrian bridge is shown in Table 6.7.

Table 6.7: Weight Calculation of Pultruded Sections for 15m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 15m			
Pultruded Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (300×90×15)	4	12.5	50
Box-Section (50×50×5)	116	1.67	193.72
Total			243.72

Weight calculation of steel sections for 15m span beam type pedestrian bridge are shown in Table 6.8.

Table 6.8: Weight Calculation of Steel Sections for 15m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 15m			
Steel Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (ISMC 350)	4	42.1	168.4
Box-Section (50×50×5)	116	4.12	477.92
Total			646.32

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

20m span Beam Type Pedestrian Bridge

Weight calculation for 20m span beam type pedestrian bridge is shown in Table 6.9.

Table 6.9: Weight Calculation of Pultruded Sections for 20m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 20m			
Pultruded Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (360×108×15)	4	15.15	60.6
Box-Section (50×50×5)	156	1.67	260.52
Total			321.12

Weight calculation of steel sections for 20m span beam type pedestrian bridge are shown in Table 6.10.

Table 6.10: Weight Calculation of Steel Sections for 20m span Beam Type Pedestrian bridge

Weight Comparison for Beam Type Pedestrian Bridge			
Span 20m			
Steel Sections	**Nos**	**Weight (kg/m)**	**Total Weight (kg/m)**
C-Section (ISMC 400)	4	49.4	197.6
Box-Section (50×50×5)	156	4.12	642.72
Total			840.32

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.
The graphical representation for the weight comparison for beam type pedestrian bridge is shown in Figure 6.1.

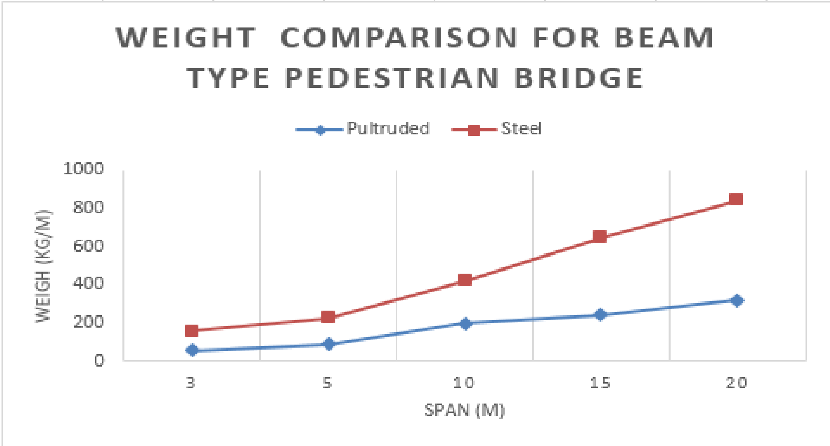


Figure 6.1: Weight Comparison for Beam Type Pedestrian Bridge

Cost Comparison for Beam Type Pedestrian Bridge

The cost of the pultruded sections are Rs.150/kg and for steel it is Rs.95/kg. Both the cost are of the material and fabrication cost. The cost of transportation and labour cost are not considered. The cost for various spans are shown in Table 6.11.

Table 6.11: Cost Comparison for Beam Type Pedestrian Bridge

CostComparison for Beam Type Pedestrian Bridge		
Spans (m)	**Pultruded Sections**	**Steel Sections**
3	Rs. 8679	Rs. 15160
5	Rs. 13269	Rs. 21676
10	Rs. 29739	Rs. 39916
15	Rs. 36558	Rs. 61400
20	Rs. 48168	Rs. 79831

The above tables shows the cost comparison for the beam type pedestrian bridge. The comparison shows that the cost of the pulturded sections are less than the steel sections. Though the cost of pultruded sections are higher than the steel sections but becasue of the less weight the cost of the pultruded sections are also less and thus pedestrian bridge with less cost can be constructed by using pultruded composites.

The graphical representation for the comparison of the cost is shown in Figure 6.2.

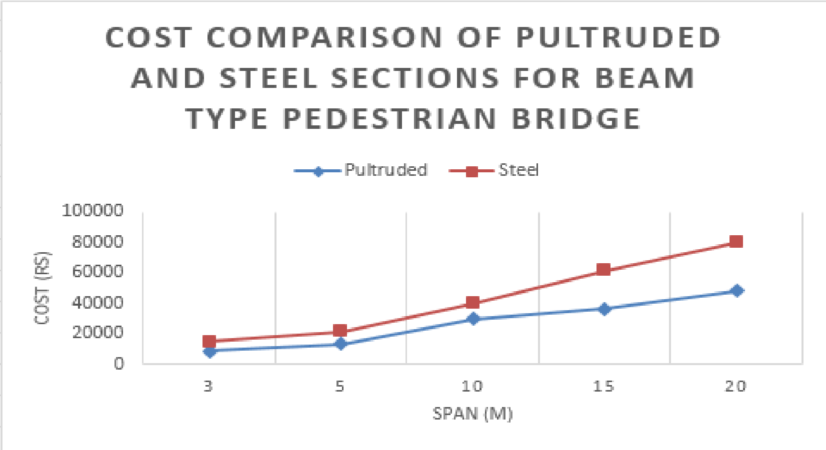


Figure 6.2: Weight Comparison for Beam Type Pedestrian Bridge

6.3 Estimation of Truss Type Pedestrian Bridge

To compare the cost the weight of the material is necessary, so firstly the comparison of weight for pultruded and steel sections are shown first.

3m span Truss Type Pedestrian Bridge

Weight calculation for 3m span beam type pedestrian bridge is shown in Table 6.12. The weight is calculated for the sections only. The weight of the connections are not considered for the weight calculation and the weight for the superstructures are only considered. Weight of the substructure are not considered.

Table 6.12: Weight Calculation of Pultruded sections for 3m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 3m			
Pultruded Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (50×50×6)	20	1.04	20.8
Angle section (50×50×6)	12	1.5	18
C-Section (120×50×6)	4	3.5	14
Total			52.8

Weight calculation of steel sections for 3m span truss type pedestrian bridge is shown in Figure 6.13.

Table 6.13: Weight Calculation of steel sections for 3m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 3m			
Steel Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (30×30×4)	14	1.8	25.2
Angle section ((45×45×6)	6	4	24
Angle section (30×30×4)	12	2.45	29.4
C-Section (ISMC 100)	4	13.8	55.2
Total			133.8

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

5m span Truss Type Pedestrian Bridge

Weight calculation for 5m span beam type pedestrian bridge is shown in Table 6.14. The weight is calculated for the sections only. The weight of the connections are not considered for the weight calculation and the weight for the superstructures are only considered. Weight of the substructure are not considered.

Table 6.14: Weight Calculation of Pultruded sections for 5m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 5m			
Pultruded Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (50×50×6)	32	1.04	33.28
Angle section (50×50×6)	20	1.5	29
C-Section (120×50×6)	6	3.5	21
Total			82.28

Weight calculation of steel sections for 5m span truss type pedestrian bridge is shown in Figure 6.15.

Table 6.15: Weight Calculation of steel sections for 5m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 5m			
Steel Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (30×30×4)	26	1.8	46.8
Angle section ((45×45×6)	10	4	40
Angle section (30×30×4)	20	2.45	49
C-Section (ISMC 100)	6	13.8	82.8
Total			218.6

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

10m span Truss Type Pedestrian Bridge

Weight calculation for 10m span beam type pedestrian bridge is shown in Table 6.16. The weight is calculated for the sections only. The weight of the connections are not considered for the weight calculation and the weight for the superstructures are only considered. Weight of the substructure are not considered.

Table 6.16: Weight Calculation of pultruded sections for 10m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 10m			
Pultruded Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (80×80×6)	32	2.81	89.92
Angle section ((50×50×6)	18	1.04	18.72
Angle section (50×50×6)	32	1.7	54.4
C-Section (120×50×6)	9	3.5	31.5
Total			194.54

Weight calculation of steel sections for 10m span truss type pedestrian bridge is shown in

Figure 6.17.

Table 6.17: Weight Calculation of steel sections for 10m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 10m			
Steel Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (50×50×5)	16	4.75	76
Angle section (60×60×10)	16	10.75	172
Angle section (30×30×4)	18	1.8	32.4
Angle section (30×30×4)	32	1.8	92.16
C-Section (ISMC 100)	9	13.8	124.2
Total			496.76

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

15m span Truss Type Pedestrian Bridge

Weight calculation for 15m span beam type pedestrian bridge is shown in Table 6.18. The weight is calculated for the sections only. The weight of the connections are not considered for the weight calculation and the weight for the superstructures are only considered. Weight of the substructure are not considered.

Table 6.18: Weight Calculation of pultruded sections for 15m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 15m			
Pultruded Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (100×100×12)	24	5.22	125.28
Angle section ((80×80×8)	24	2.81	67.44
Angle section (50×50×6)	26	1.04	27.07
Angle section (80×80×6)	48	3.6	172.8
C-Section (120×50×6)	13	3.5	45.4
Total			438.06

Weight calculation of steel sections for 15m span truss type pedestrian bridge is shown in Figure 6.19.

Table 6.19: Weight Calculation of steel sections for 15m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 15m			
Steel Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (70×70×8)	24	10.4	249.6
Angle section (60×60×10)	24	10.75	258
Angle section (50×50×5)	26	4.75	123.5
Angle section (50×50×5)	48	7.6	364.8
C-Section (ISMC 100)	13	13.8	179.4
Total			1175.3

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

20m span Truss Type Pedestrian Bridge

Weight calculation for 15m span beam type pedestrian bridge is shown in Table 6.20. The weight is calculated for the sections only. The weight of the connections are not considered for the weight calculation and the weight for the superstructures are only considered. Weight of the substructure are not considered.

Table 6.20: Weight Calculation of pultruded sections for 20m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 20m			
Pultruded Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (160×160×12)	40	13.68	547.2
Angle section ((80×80×8)	22	2.25	49.5
Angle section (80×80×6)	40	5.04	201.6
C-Section (120×50×6)	11	3.5	38.5
Total			836.8

Weight calculation of steel sections for 20m span truss type pedestrian bridge is shown in Figure 6.21.

Table 6.21: Weight Calculation of steel sections for 20m span Truss Type Pedestrian Bridge

Weight Comparison for Truss Type Pedestrian Bridge			
Span 20m			
Steel Section	**Nos.**	**Weight per (kg)**	**Total Weight (kg)**
Angle section (110×110×8)	20	26.8	536
Angle section (110×110×15)	20	48.4	968
Angle section (50×50×5)	22	4.75	104.5
Angle section (50×50×5)	40	10.64	425.6
C-Section (ISMC 100)	11	13.8	151.8
Total			2185.9

The results shows that the weight of the pultruded sections are less than the steel sections and as a result of that the overall weight of the structure is also less. So, by the use of pultruded sections the weight of the structure can be reduced effectively.

The graphical representation for the weight comparison for truss type pedestrian bridge is shown in Figure 6.3.

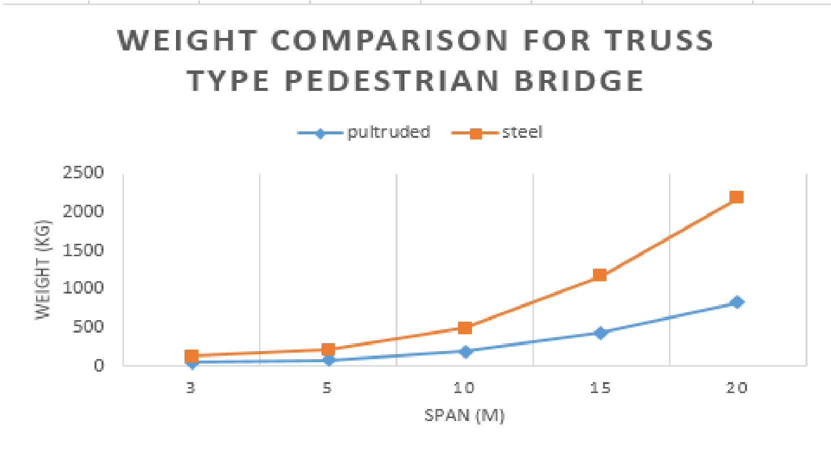


Figure 6.3: Weight Comparison for Truss Type Pedestrian Bridge

Cost Comparison for Truss Type Pedestrian Bridge

The cost of the pultruded sections are Rs.150/kg and for steel it is Rs.95/kg. Both the cost are of the material and fabrication cost. The cost of transportation and labour cost are not considered. The cost for various spans are shown in Table 6.22.

Table 6.22: Cost Comparison for Truss Type Pedestrian Bridge

CostComparison for Beam Type Pedestrian Bridge		
Spans (m)	**Pultruded Sections**	**Steel Sections**
3	Rs. 7920	Rs. 12711
5	Rs. 12492	Rs. 20767
10	Rs. 29181	Rs. 47193
15	Rs. 65709	Rs. 111654
20	Rs. 125520	Rs. 207661

The above table shows the cost comparison for the truss type pedestrian bridge. The comparison shows that the cost of the pulturded sections are less than the steel sections. Though the cost of pultruded sections are higher than the steel sections but becasue of the less weight the cost of the pultruded sections are also less and thus pedestrian bridge with less cost can be constructed by using pultruded composites.

The graphical representation for the comparison of the cost is shown in Figure 6.4.

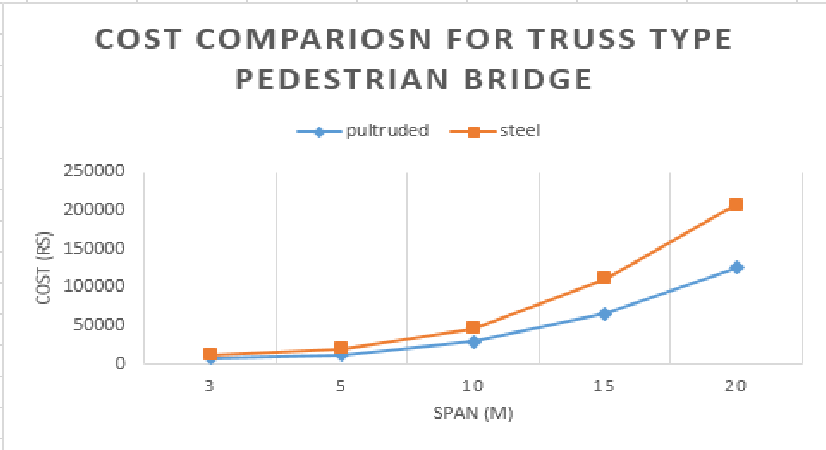


Figure 6.4: Weight Comparison for Beam Type Pedestrian Bridge

6.4 Summary

In this chapter the cost estimation for the beam type pedestrian bridge and truss type pedestrian bridge is carried out to estimate the material cost.The cost is calculated for materials only. Labour cost and transportation cost is not carried out.

Chapter 7

Summary and Conclusion

7.1 Summary

Over the few years, the materials which were used in the construction of pedestrian bridges were wood, steel and reinforced concrete. The effect of environment on these materials has in general, a significant impact on cost of the structure due to its maintenance and rehabilitation. In addition, the need of faster and lighter and less maintenance structure has lead to the development of the new structural materials. The new materials are known as composites. These materials were first used in 1950s. A momentous part of the composites that are used by modern society is the Plastic Reinforced with various types of fibers, also named by fiber reinforced polymer (FRP). The application field of FRP was restricted to aerospace and marine industries. However in the last few years, the need of the construction industry, the advances in the research in construction field and in addition the decrease in cost of FRP production, acquiesce the used of composites in construction industry. These structural materials have been used in number of structures to-date such as pedestrian bridges, cooling tower and walkways. Due to many advantages of composites, they have been used in several ways in construction of bridges

The pedestrian bridge using pultruded composites was analysed under static load case.Two different profiles of the pedestrian bridge were considered namely Beam Type and Truss Type Pedestrian Bridge. Five different spans were considered for the analysis and design. The different spans were 3m, 5m, 10m, 15m and 20m. The analysis was done using staad pro software. The design of the pedestrian bridge was done using Fiberline Design Manual and National Research Council of Italy.

The parametric study was carried out for the Beam Type and Truss Type Pedestrian Bridge. The pultruded sections were compared with each other to determine the most optimum section for the particular type of pedestrian bridge. The pultruded composites were also compared with steel sections to determine the difference in the load carrying capacity of both the materials. In beam type pedestrian bridge the moment capacity was kept constant and different parameters like shear capacity, deflection and weight were compared. Similarly for truss type pedestrian bridge the axial load carrying capacity was kept constant and weight was compared. The cost estimation was also carried out for both type of pedestrian bridge.

7.2 Conclusion

The main aim of the work was to analyse and design the pedestrian bridge using pultruded composites. Two type of pedestrian bridge namely beam type and truss type pedestrian bridge was analysed and designed. Parametric study was also carried out for the pedestrian bridge and the conclusions made from the parametric study are as follows:

a) Beam Type Pedestrian Bridge

- In beam type pedestrian bridge for the pultruded sections C-Section comes out to be the most economical section than the I-Section and Box-Section.
- The results shows that by keeping moment capacity constant the shear capacity of the pultruded sections are less than the steel sections.
- The deflection of the pultruded sections are more than the steel sections.
- The weight of the pultruded sections are less than the steel sections.

b) Truss Type Pedestrian Bridge

- In truss type pedestrian bridge for the pultruded sections the angle section is more economical than the box sections.
- The parametric study shows that by keeping axial capacity constant the weight of the pultruded sections are less than the steel sections.

From all these above conclusions it can be said that bu using pultruded composites the self weight of the structures can be reduced. As there is negligible effect of environment effect on these materials the maintance cost can also be reduced and thus the life span of the structure can be increased.

7.3 Future Scope of Work

The present work can be used as an input for further work explained as follows:

- The analysis and design of a pedestrian bridge using pultruded composites under wind loads.
- Parametric study of the pedestrian bridge using pulturded composites and aluminium.
- Parametric study of the pedestrian bridge using pulturded composites and cold form steel.
- To study the pedestrian bridge using pultuded composites by Finite Element Method.

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Appendix A

Analysis and Design Sheets for Pedestrian Bridge

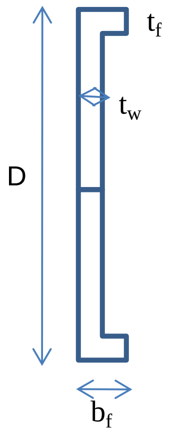
Job :	Beam Type Pedestrian Bridge	Prepared by	DSS	Note No.
		Checked by	0	
Title :	Span 3m	Date	1-Sep-15	Revision

MATERIAL PROPERTIES

E	Modulus of Elasticity	38.42	kN/mm^2
ν	Poisson's Ratio	0.33	
ϒ	Density	1850	kg/m^3

GEOMETRIC PROPERTIES

(C-Section)



L	length of beam	3000	mm
D	Depth of the section	200	mm
b_f	Width of flange	60	mm
d	depth	180	mm
t_f	Thickness of flange	10	mm
t_w	Thickness of web	10	mm
A	Cross-Section area	3000	mm^2
V	volume	9E+06	mm^3
X_{cog}	Centre of Gravity	15	mm
Y_{cog}	Centre of Gravity	100	mm
I_{xx}	Area moment of Inertia	2E+07	mm^4
I_{yy}	Area moment of Inertia	825000	mm^4
W_{xx}	Section Modulus	157000	mm^3
W_{yy}	Section Modulus	18333	mm^3

Job :	Beam Type Pedestrian Bridge	Prepared by	DSS	Note No.	
		Checked by	0		
Title :	Span 3m	Date	1-Sep-15	Revision	R0

DESIGN OF BEAM

	L	Span	3.0	m	
	q	Live Load	3.75	KN/m	
	Ψ	Partial Coefficient	1.5		
	δ	Deflction limit	10.000	mm	L/300
	K_M	Moment coefficient	0.125		Fiberline manual (Table 3.1)
	K_V	Shear coefficeint	0.5		Fiberline manual (Table 3.1)
$P_d = 1.5\times3.75$	P_d	Load	5.6	KN/m	
$M_d = 5.6\times3^2/8$	M_d	Moment	6.3	KN.m	
$V_d = 5.6\times3/2$	V_d	Shear Force	8.4	KN	
$\sigma_b=M_d/W_{xx}$	σ_b	Bending Stress	60.5	Mpa	
$f_{b,f,d}=450/1.5$	$f_{b,f,d}$	Permissible bending stress	300.0	Mpa OK	
$\tau_{ma} = V_d/A$	τ_{ma}	Shear stress	4.7	Mpa	
$\tau = 25/1.5$	τ	Permissible shear stress	16.7	Mpa OK	

DEFLECTION CHECK

`

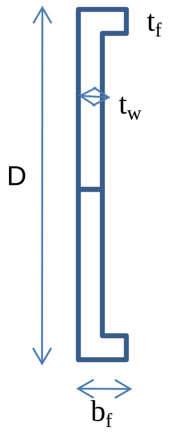
	$K_{\delta M}$		0.013		Fiberline manual (Table 3.1)
	$K_{\delta V}$		0.125		Fiberline manual (Table 3.1)
	δ	Deflection	6.6534	mm	
	δ/L	Deflection Limit	10	mm OK	

Job :	Beam Type Pedestrian bridge	Prepared by	DSS	Note No.
		Checked by	0	
Title :	Span 5m	Date	1-Sep-15	Revision

MATERIAL PROPERTIES

E	Modulus of Elasticity	38.42	kN/mm^2
ν	Poisson's Ratio	0.33	
ϒ	Density	1850	kg/m^3

GEOMETRIC PROPERTIES (C-Section)



L	length of beam	5000	mm
D	Depth of the section	300	mm
b_f	Width of flange	90	mm
d	depth	270	mm
t_f	Thickness of flange	15	mm
t_w	Thickness of web	15	mm
A	Cross-Section area	6750	mm^2
V	volume	3E+07	mm^3
X_{cog}	Centre of Gravity	22.5	mm
Y_{cog}	Centre of Gravity	150	mm
I_{xx}	Area moment of Inertia	8E+07	mm^4
I_{yy}	Area moment of Inertia	4E+06	mm^4
W_{xx}	Section Modulus	529875	mm^3
W_{yy}	Section Modulus	61875	mm^3

Job :	Beam Type Pedestrian bridge	Prepared by	DSS	Note No.		
		Checked by	0			
Title :	Span 5m	Date	1-Sep-15	Revision	R0	

DESIGN OF BEAM

L	Span	5.0	m		
q	Live Load	3.75	KN/m		
Ψ	Partial Coefficient	1.5			
δ	Deflction limit	16.667	mm		L/300
K_M	Moment coefficient	0.125			Fiberline manual (Table 3.1)
K_V	Shear coefficeint	0.5			Fiberline manual (Table 3.1)
P_d	Load	5.6	KN/m		
M_d	Moment	17.6	KN.m		
V_d	Shear Force	14.1	KN		
σ_b	Bending Stress	49.8	Mpa		
$f_{b,f,d}$	Permissible bending stress	300.0	Mpa	OK	
τ_{ma}	Shear stress	3.5	Mpa		
τ	Permissible shear stress	20	Mpa	OK	

DEFLECTION CHECK `

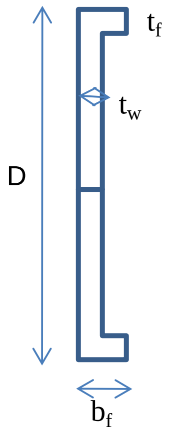
$K_{\delta M}$		0.013			Fiberline manual (Table 3.1)
$K_{\delta V}$		0.125			Fiberline manual (Table 3.1)
δ	Deflection	10.065	mm		
δ/L	Deflection Limit	16.667	mm	OK	

Job :	Beam Type Pedestrian Bridge	Prepared by	DSS	Note No.
		Checked by	0	
Title :	Span 10m	Date	1-Sep-15	Revision

MATERIAL PROPERTIES

E	Modulus of Elasticity	38.42	kN/mm^2
ν	Poisson's Ratio	0.33	
ϒ	Density	1850	kg/m^3

GEOMETRIC PROPERTIES (C-Section)



L	length of beam	10000	mm
D	Depth of the section	420	mm
b_f	Width of flange	126	mm
d	depth	360	mm
t_f	Thickness of flange	30	mm
t_w	Thickness of web	30	mm
A	Cross-Section area	18360	mm^2
V	volume	2E+08	mm^3
X_{cog}	Centre of Gravity	34.765	mm
Y_{cog}	Centre of Gravity	210	mm
I_{xx}	Area moment of Inertia	4E+08	mm^4
I_{yy}	Area moment of Inertia	2E+07	mm^4
W_{xx}	Section Modulus	2E+06	mm^3
W_{yy}	Section Modulus	230809	mm^3

	Beam Type Pedestrian bridge	Prepared by	DSS	Note No.	
		Checked by	0		
	Span 10m	Date	1-Sep-15	Revision	R0

DESIGN OF BEAM

L	Span	10.0	m		
q	Live Load	3.75	KN/m		
Ψ	Partial Coefficient	1.5			
δ	Deflction limit	33.333	mm		L/300
K_M	Moment coefficient	0.125			Fiberline manual (Table 3.1)
K_V	Shear coefficeint	0.5			Fiberline manual (Table 3.1)
P_d	Load	5.6	KN/m		
M_d	Moment	70.3	KN.m		
V_d	Shear Force	28.1	KN		
σ_b	Bending Stress	36.5	Mpa		
$f_{b,f,d}$	Permissible bending stress	300.0	Mpa	OK	
τ_{ma}	Shear stress	2.6	Mpa		
τ	Permissible shear stress	20	Mpa	OK	

DEFLECTION CHECK

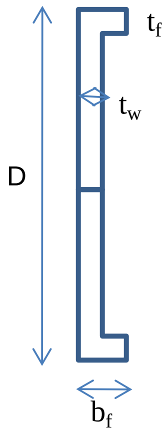
$K_{\delta M}$		0.013			Fiberline manual (Table 3.1)
$K_{\delta V}$		0.125			Fiberline manual (Table 3.1)
δ	Deflection	31.454	mm		
δ/L	Deflection Limit	33.333	mm	OK	

Job :	Beam Type Pedestrian Bridge	Prepared by	DSS	Note No.
		Checked by	0	
Title :	Span 15m	Date	1-Sep-15	Revision

MATERIAL PROPERTIES

E	Modulus of Elasticity	38.42	kn/mm^2
ν	Poisson's Ratio	0.33	
ϒ	Density	1850	kg/m^3

GEOMETRIC PROPERTIES (C-Section)



L	length of beam	7500	mm
D	Depth of the section	300	mm
b_f	Width of flange	90	mm
d	depth	270	mm
t_f	Thickness of flange	15	mm
t_w	Thickness of web	15	mm
A	Cross-Section area	6750	mm^2
V	volume	50625000	mm^3
X_{cog}	Centre of Gravity	22.5	mm
Y_{cog}	Centre of Gravity	150	mm
I_{xx}	Area moment of Inertia	79481250	mm^4
I_{yy}	Area moment of Inertia	4176563	mm^4
W_{xx}	Section Modulus	529875	mm^3
W_{yy}	Section Modulus	61875	mm^3

Job :	Beam Type Pedestrian bridge	Prepared by	DSS	Note No.		
		Checked by	0			
Title :	Span 15m	Date	1-Sep-15	Revision	R0	

DESIGN OF BEAM

L	Span	7.5	m	
q	Live Load	3.75	KN/m	
Ψ	Partial Coefficient	1.5		
δ	Deflction limit	25.000	mm	L/300
K_M	Moment coefficient	0.125		Fiberline manual (Table 3.1)
K_V	Shear coefficeint	0.5		Fiberline manual (Table 3.1)
P_d	Load	5.6	KN/m	
M_d	Moment	39.6	KN.m	
V_d	Shear Force	21.1	KN	
σ_b	Bending Stress	74.6	Mpa	
$f_{b,f,d}$	Permissible bending stress	300.0	Mpa OK	
τ_{ma}	Shear stress	5.2	Mpa	
τ	Permissible shear stress	20	Mpa OK	

DEFLECTION CHECK

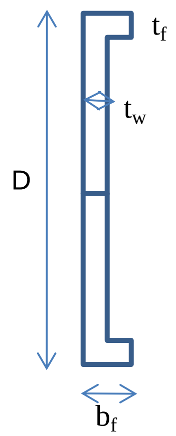
$K_{\delta M}$		0.0054		Fiberline manual (Table 3.1)
$K_{\delta V}$		0.125		Fiberline manual (Table 3.1)
δ	Deflection	21.166	mm	
δ/L	Deflection Limit	25	mm OK	

Job :	Beam Type Pedestrian Bridge	Prepared by	DSS	Note No.
		Checked by	0	
Title :	Span 20m	Date	1-Sep-15	Revision

MATERIAL PROPERTIES

E	Modulus of Elasticity	38.42	kN/mm^2
ν	Poisson's Ratio	0.33	
ϒ	Density	1850	kg/m^3

GEOMETRIC PROPERTIES (C-Section)



L	length of beam	10000	mm
D	Depth of the section	360	mm
b_f	Width of flange	108	mm
d	depth	330	mm
t_f	Thickness of flange	15	mm
t_w	Thickness of web	15	mm
A	Cross-Section area	8190	mm^2
V	volume	8E+07	mm^3
X_{cog}	Centre of Gravity	25.896	mm
Y_{cog}	Centre of Gravity	180	mm
I_{xx}	Area moment of Inertia	1E+08	mm^4
I_{yy}	Area moment of Inertia	7E+06	mm^4
W_{xx}	Section Modulus	785513	mm^3
W_{yy}	Section Modulus	91058	mm^3

Job :	Beam Type Pedestrian Bridge	Prepared by	DSS	Note No.	
		Checked by	0		
Title :	Span 20m	Date	1-Sep-15	Revision	R0

DESIGN OF BEAM

L	Span	10.0	m	
q	Live Load	3.75	KN/m	
Ψ	Partial Coefficient	1.5		
δ	Deflction limit	33.333	mm	L/300
K_M	Moment coefficient	0.125		Fiberline manual (Table 3.1)
K_V	Shear coefficeint	0.5		Fiberline manual (Table 3.1)
P_d	Load	5.6	KN/m	
M_d	Moment	70.3	KN.m	
V_d	Shear Force	28.1	KN	
σ_b	Bending Stress	89.5	Mpa	
$f_{b,f,d}$	Permissible bending stress	300.0	Mpa OK	
τ_{ma}	Shear stress	5.7	Mpa	
τ	Permissible shear stress	20	Mpa OK	

DEFLECTION CHECK

$K_{\delta M}$		0.00542		Fiberline manual (Table 3.1)
$K_{\delta V}$		0.125		Fiberline manual (Table 3.1)
δ	Deflection	28.14855	mm	
δ/L	Deflection Limit	33.33333	mm OK	

Appendix B

Publications

1) **Shah D.S.,Koshti U.K,Dave U.V**, "Comparison of guidelines for pultruded composites and steel", 1^{th} National Conference on Recent Advances in CIVIL ENGINEERING (RACE-2016) Department of Civil Engineering and Applied Mechanics, Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat.

2) **Shah D.S.,Koshti U.K,Dave U.V**, "Design of a Pedestrian bridge using pultruded materials", 8^{th} National Civil Engineering Students Symposuim (AAKAR), Indian Institute of Technology Bombay, Maharashtra.

3) **Shah D.S.,Koshti U.K,Dave U.V**,"Comparison of guidelines for pultruded composites", 8^{th} National Conference on Emerging Vistas of Technology (NCEVT2016) PARUL UNIVERSITY, Vadodara, India.

4) **Shah D.S.,Koshti U.K,Dave U.V**, "Pultruded Composites for Structural Applications", National Level Techno-Management Colloquium- NU-TECH'16, Institute of Technology, Nirma University, Ahmedabad, Gujarat.