

Table of Contents

1. Introduction	1
1.1. Pedestrian Bridge.....	1
2. Layout of Footbridge	1
3. Materials and Design Parameters.....	4
3.1. Vertical Clearance.....	4
3.2. Railing Height	4
4. Location of Pedestrian Bridge	5
5. Structural System.....	6
5.1. Deck and Supports.....	6
6. Load Analysis.....	6
6.1. Dead Load Analysis.....	6
6.2. Live Load Analysis.....	7
6.3. Wind Load Analysis.....	8
7. Restraint Mechanism	9
References.....	10

List of Figure

Figure 1 Foot Bridge Plan	1
Figure 2 Beam Layout	2
Figure 3 Front View of Bridge.....	2
Figure 4 Side View.....	3
Figure 5 3D Model of Proposed Bridge.....	3
Figure 6 Front View of Bridge with Railing.....	5
Figure 7 College of Engineering and the Library buildings University of Qatar... ..	5
Figure 8 Cross Section of Pedestrian Bridge.....	5
Figure 9 Cross Section of Bridge Deck 3D Model.....	6
Figure 10 Cross Section of Bridge.....	6
Figure 11 Transvers Beam.....	6
Figure 12 Pedestrian Loading AASHTO LRFD	7

List of Table

Table 1 Vertical Clearance For Bridge.....	4
Table 2 Values For V0 and Z0 From AASHTO LRFD.....	8

DESIGN OF PEDESTRIAN FOOTBRIDGE

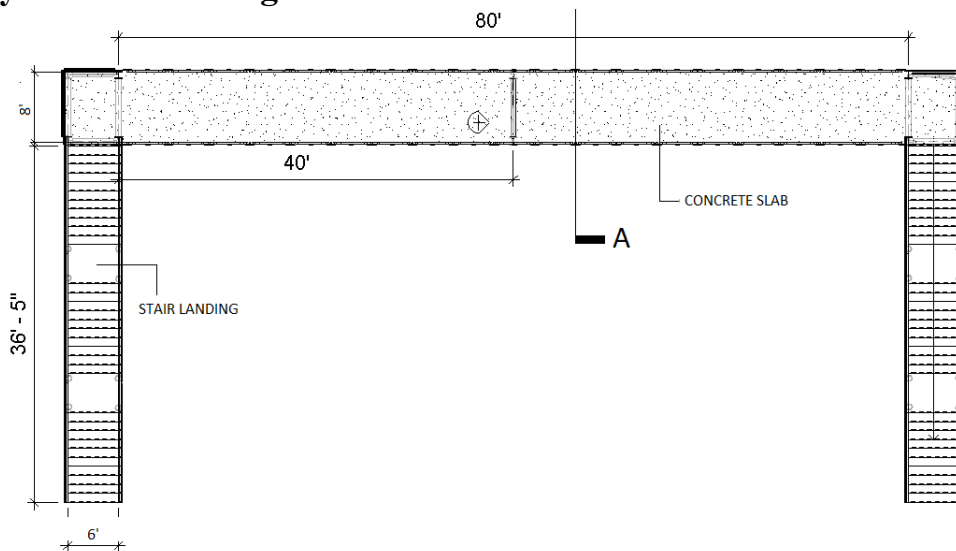
1. Introduction

1.1. Pedestrian Bridge

In order to allow pedestrians to cross roadways, bodies of water, and other barriers safely and effectively, pedestrian foot bridges are crucial pieces of urban infrastructure. From the standpoint of civil engineering, careful consideration of a number of criteria is needed during the design and construction of these structures to guarantee their functioning, robustness, and safety. Before creating a design that satisfies both structural and aesthetic requirements, engineers must evaluate the expected pedestrian load, the surrounding environment, and the unique site constraints.

In the field of civil engineering, the selection of materials holds immense significance in the construction of pedestrian foot bridges. Engineers face the critical task of choosing materials that can effectively withstand the diverse environmental challenges posed by factors such as fluctuating weather conditions, corrosion, and the vibrational impact of traffic. Furthermore, meticulous attention is given to ensuring that the structural integrity of the bridge aligns with local building codes and standards, thereby guaranteeing the safety of pedestrians who utilize the structure. Emphasizing the importance of a robust foundation design is imperative, particularly in regions prone to seismic activity or featuring unstable soil conditions. The civil engineering perspective on pedestrian foot bridges necessitates a holistic approach, encompassing considerations of structural strength, environmental resilience, and safety measures to craft a durable and functional infrastructure component within urban landscapes.

2. Layout of Footbridge



*Figure 1 Foot Bridge Plan
Source: From Revit 3D Model*

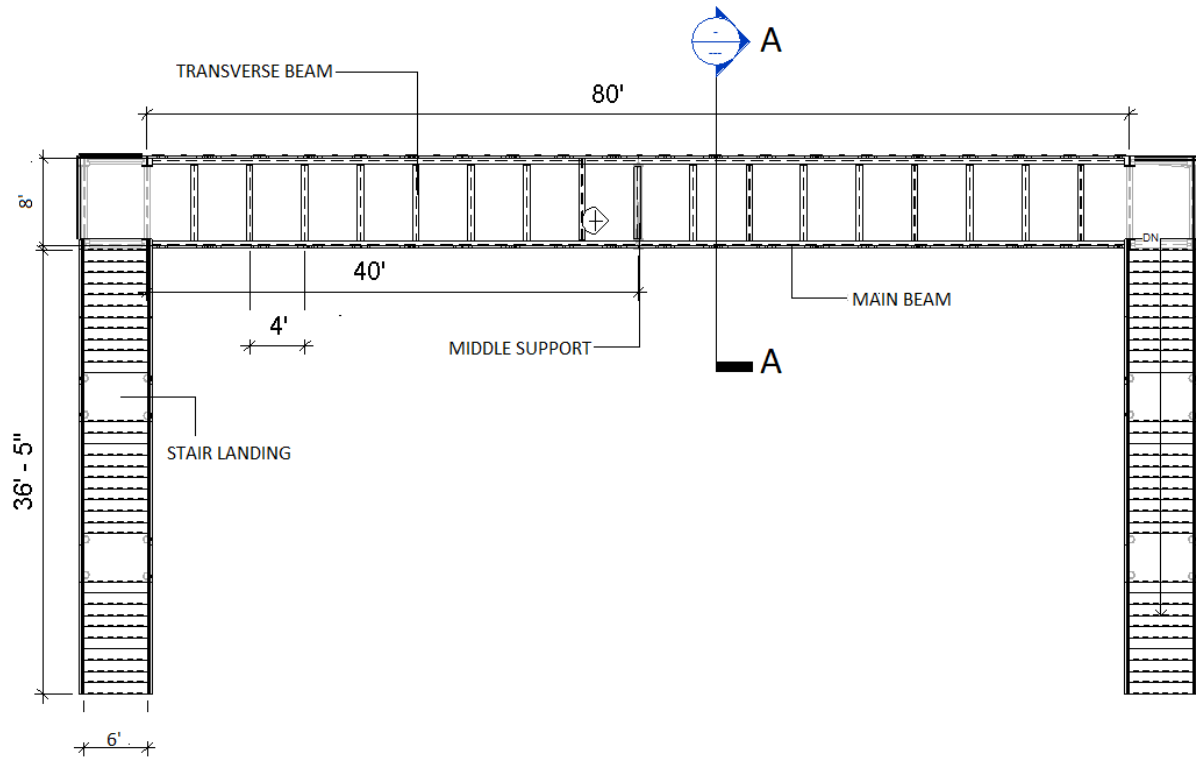


Figure 2 Beam Layout
Source: From Revit 3D Model

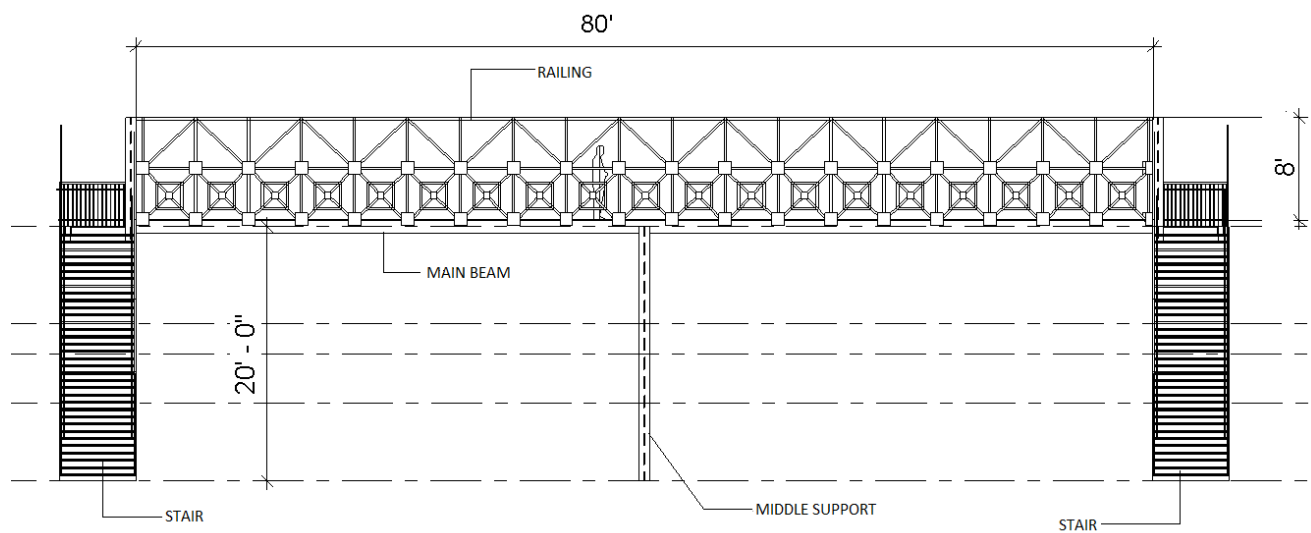


Figure 3 Front View of Bridge
Source: From Revit 3D Model

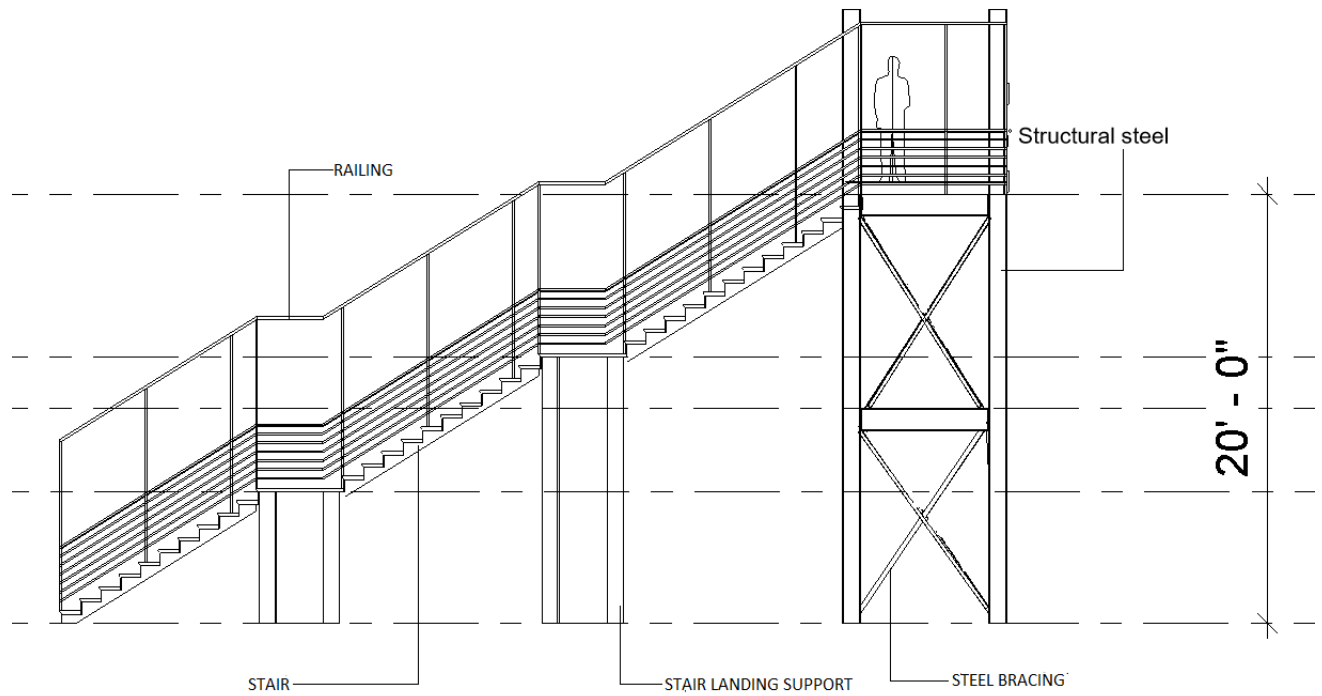


Figure 4 Side View
Source: From Revit 3D Model

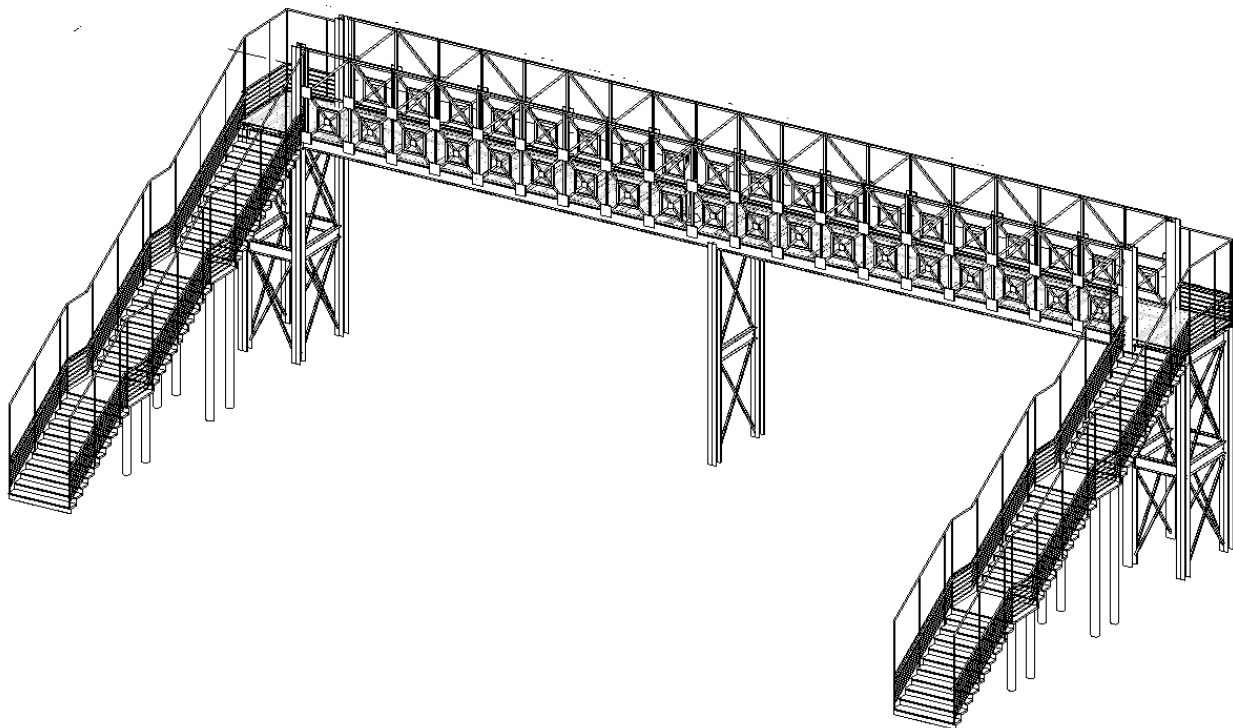


Figure 5 3D Model of Proposed Bridge
Source: From Revit 3D Model

3. Materials and Design Parameters

Total length of bridge = 80 ft	Span l = 40 ft Single Bay	Width of bridge = 8 ft
Concrete slab thickness = 6 in	Finish Floor Load = 40 Psf	Railing load = 550 lb/ft
$F_c' = 4000$ Psi	$F_y = 60000$ Psi	Structural Steel = A36
Steel Density = 475 lb/ft ³	Concrete Density = 150 lb/ft ³	Clearance Height = 20 ft

3.1. Vertical Clearance

According to AASHTO LRFD Specification Section 2.1.3, as shown in table below the minimum vertical clearance for a pedestrian bridge over a highway is 17 feet 4 inches. However, in our specific case, we will ensure a vertical clearance of 20 feet. This decision aligns with safety standards and aims to enhance the overall usability and safety of the pedestrian bridge.

Table 2.1.3.1 Vertical Clearances for Underpass Bridges

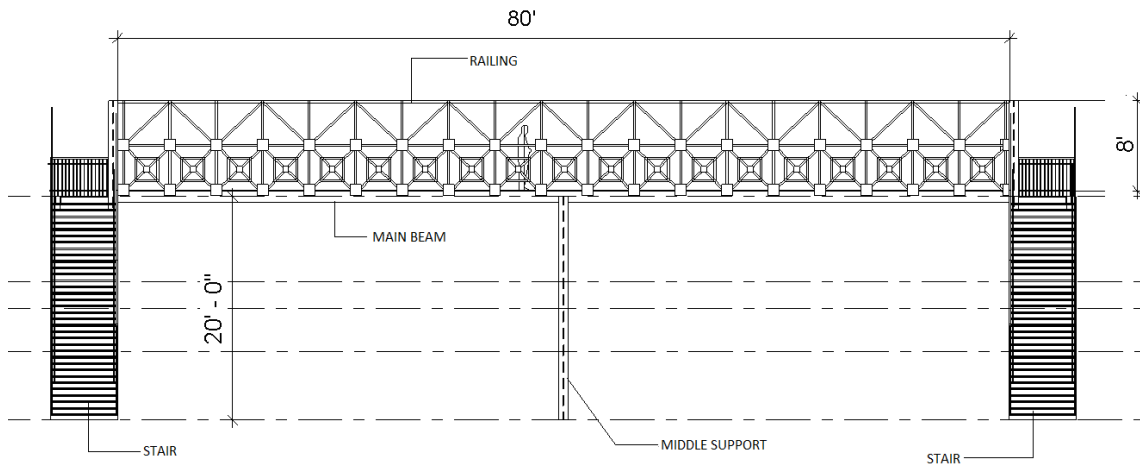
TYPE OF STRUCTURE	MINIMUM VERTICAL CLEARANCE FOR NEW BRIDGES ①②	MINIMUM VERTICAL CLEARANCE UNDER EXISTING BRIDGES (FOR PAVEMENT RECONSTRUCTION PROJECTS) ③
Trunk Highway Under Roadway or Railroad Bridge (Super Load OSOW Corridors) ④	16'-6"	16'-6"
Trunk Highway Under Roadway or Railroad Bridge	16'-4"	16'-0"
Trunk Highway Under Pedestrian Bridge ⑤	17'-4"	17'-0"
Trunk Highway Under Sign Bridge ⑤	17'-4"	17'-0"
Railroad Under Trunk Highway Bridge ⑥	23'-0"	NA
Portal Clearances on Truss or Arch ⑦	20'-4"	20'-0"

Table 1 Vertical Clearance for Bridge
Source: AASHTO LRFD Table 2.1.3.1

3.2. Railing Height

As stipulated in AASHTO LRFD section 2.4.1.2, it is mandatory to incorporate protective screening on both sides of the bridge, with a preference for a chain link fence system or a railing system. The prescribed height for the fence or railing is 8 feet above the sidewalk's top. In cases

where there are special aesthetic treatments involving ornamental railings, a minimum height of 6 feet is permissible. Furthermore, if a fence or railing system is necessitated on retaining walls connected to the bridge, it is advisable to maintain uniformity by employing the same system, either a chain link fence or a railing, consistently throughout the structure. This guideline ensures a cohesive approach to safety measures and visual aesthetics across both the bridge and its associated retaining walls.



*Figure 6 Front View of Bridge with Railing
Source: From Revit 3D Model*

4. Location of Pedestrian Bridge

The pedestrian footbridge, situated in Qatar, serves the purpose of connecting the H07 College of Engineering with the Library buildings. This essential infrastructure facilitates convenient and safe movement between these two significant campus structures. Figure 1 shows the location of the bridge.



*Figure 7 College of Engineering and the Library buildings University of Qatar
Source: From Google Earth*

5. Structural System

5.1. Deck and Supports

The pedestrian bridge deck is depicted in Figure 8 and Figure 9. A 6-inch slab is supported by longitudinal and transverse steel girders, providing the structural foundation for the bridge.

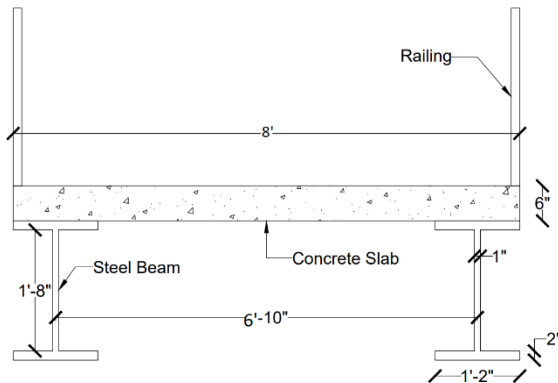


Figure 8 Cross Section of Pedestrian Bridge
Source: From Revit 3D Model

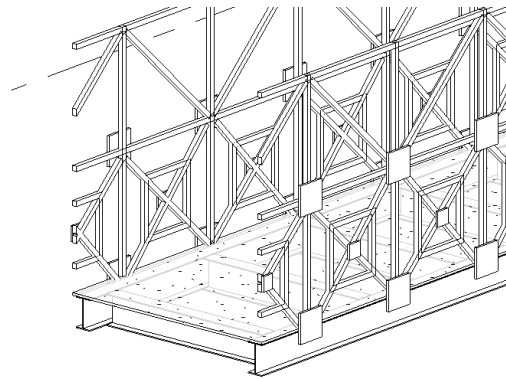


Figure 9 Cross Section of Bridge Deck 3D Model
Source: From Revit 3D Model

6. Load Analysis

Load and structural analysis of bridges constitute a fundamental aspect of civil engineering, ensuring the robustness and safety of these critical infrastructure elements. Bridge engineers carefully consider all the loads that a bridge may experience: active loads from passing cars or pedestrians, dead loads from the weight of the structure itself, and environmental loads from wind and seismic activity. In order to make sure the structure can sustain its intended use, structural analysis entails evaluating how these loads interact with the bridge's components and calculating stresses, strains, and deflections.

6.1. Dead Load Analysis

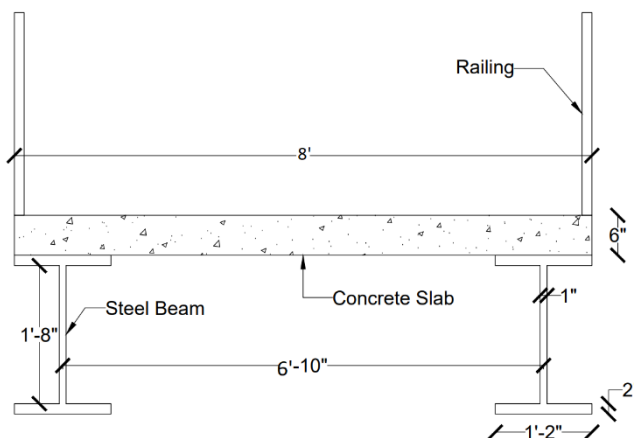


Figure 10 Cross Section of Bridge
Source: From Revit 3D Model

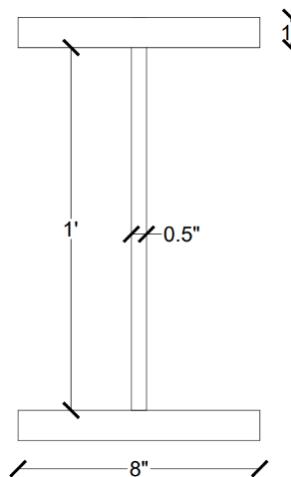


Figure 11 Transvers Beam
Source: From Revit 3D Model

$$\text{Slab} = \frac{6}{12} \times 6.833 \times 1 \times 150 = 512.5 \text{ lb/ft}$$

$$\text{Beam/Girder} = \left[\left(\frac{1.5}{12} \times \frac{14}{12} \times 1 \right) \times 2 \times 475 \right] + \left(\frac{20}{12} \times \frac{1}{12} \times 1 \times 475 \right) = 204.5 \text{ lb/ft}$$

$$\text{Transverse Beam} = \left[\left(\frac{1}{12} \times \frac{8}{12} \times 1 \right) \times 2 \times 475 \right] + \left(\frac{12}{12} \times \frac{0.5}{12} \times 1 \times 475 \right) \times 6.833 = 495.86 \text{ lb}$$

$$\text{Number of transverse Beam in 40ft length} = 8$$

$$\text{Total weight of 8 beam} = 495.86 \times 8 = 3966.9 \text{ lb}$$

$$\text{Dead load of transverse beam in 40ft length} = \frac{3966.9}{40} = 99.17 \text{ lb/ft}$$

$$\text{Finish Floor} = 40 \times 6.833 = 273.32 \text{ lb/ft}$$

$$\text{Railing Load} = 550 \text{ lb/ft Assumed}$$

$$\text{Total Dead Load } w = 512.5 + 204.5 + 99.17 + 273.32 + 550 = 1649.49 \text{ lb/ft}$$

$$\text{Moment for Dead load} = \frac{wl^2}{8} = \frac{1649.49 \times 40^2}{8} = 340065 \text{ lb-ft} = 340 \text{ k-ft}$$

$$\text{Shear For Dead load} = \frac{1649.49 \times 40}{2} = 32989.8 \text{ lb} = 32.98 \text{ kip}$$

6.2. Live Load Analysis

In accordance with the AASHTO LRFD bridge design specifications specifically tailored for pedestrian bridges, it is mandated that these structures undergo design considerations accommodating a uniform pedestrian loading of 90 pounds per square foot (psf). The design process entails modeling the bridge to withstand this pedestrian loading uniformly across its surface, with a particular emphasis on generating the maximum load effects. Notably, in the context of this loading scenario, there is no requirement to factor in allowances for dynamic loads. This stipulation reflects the engineering emphasis on optimizing the structural integrity of pedestrian bridges under typical pedestrian loading conditions, ensuring robustness and safety in accordance with AASHTO LRFD guidelines.

3.1—PEDESTRIAN LOADING (PL)

Pedestrian bridges shall be designed for a uniform pedestrian loading of 90 psf. This loading shall be patterned to produce the maximum load effects. Consideration of dynamic load allowance is not required with this loading.

Figure 12 Pedestrian Loading AASHTO LRFD
Source: From AASHTO LRFD

$$\text{Live Load } LL = 90 \times 40 = 3600 \text{ lb/ft}$$

$$\text{Moment for live load} = \frac{wl^2}{8} = \frac{3600 \times 40^2}{8} = 720000 \text{ lb} - \text{ft} = 720 \text{ k} - \text{ft}$$

$$\text{Shear for live load} = \frac{3600 \times 40}{2} = 72000 \text{ lb} = 72 \text{ kip}$$

6.3. Wind Load Analysis

$$V_{DZ} = 2.5V_0 = \left(\frac{V_{30}}{V_B}\right) \ln\left(\frac{Z}{Z_0}\right) \quad \text{AASHTO LRFD Equation 3.8.1.1-1}$$

Where:

V_{DZ} = Design wind velocity at design elevation, Z (mph)

V_0 = friction velocity, see Table 3.5.1.1-1

V_{30} = wind velocity at 30.0 feet above low ground or design water level (mph)

V_B = base wind velocity, 100 mph

Z = height of structure above low ground or water level at which wind loads are being calculated

Z_0 = friction length, see Table 3.5.1.1-1

Table 3.8.1.1-1—Values of V_0 and Z_0 for Various Upstream Surface Conditions

Condition	Open Country	Suburban	City
V_0 (mph)	8.20	10.90	12.00
Z_0 (ft)	0.23	3.28	8.20

Table 2 Values For V_0 and Z_0 From AASHTO LRFD

Source: AASHTO LRFD Table 3.8.1.1-1

$$V_0 = 12 \quad Z_0 = 8.20$$

$$V_B = V_{30} = 100 \text{ mph}$$

$$V_{DZ} = 2.5V_0 \times \left(\frac{V_{30}}{V_B}\right) \ln\left(\frac{Z}{Z_0}\right) = 2.5 \times 12 \times \left(\frac{100}{100}\right) \ln\left(\frac{20}{8.20}\right) = 26.74 \text{ mph}$$

7. Restraint Mechanism

Let's consider a scenario where the temperature experiences variations, ranging from 42 degrees Celsius in the summer to -2 degrees Celsius in the winter. In light of these temperature fluctuations, the imperative task at hand involves the calculation of thermal expansion in the bridge. Taking into account the different thermal conditions in summer and winter, this calculation is essential to comprehending how the structure reacts to temperature variations. In order to ensure the bridge's robustness and functionality across a variety of climatic circumstances, engineers can make well-informed judgments about the material qualities and structural design by calculating the thermal expansion.

$$T_{emax} = T_{max} + 2 = 42 + 2 = 44$$

$$T_{emin} = T_{min} + 7 = -2 + 7 = 5$$

$$\text{Maximum Possible Rise} = 44 - 8 = 36$$

$$\text{Maximum Possible Fall} = 25 - 5 = 20$$

$$\text{Maximum Expansion} = \alpha \Delta T L = 12 \times 10^{-6} \times 36 \times 40 \times 12 = 0.21 \text{ in}$$

$$\text{Maximum Contraction} = \alpha \Delta T L = 12 \times 10^{-6} \times 20 \times 40 \times 12 = 0.11 \text{ in}$$

$$\text{Maximum possible Movement} = 0.21 + 0.11 = 0.32 \text{ in}$$

In order to accommodate the effects of temperature, as well as moments resulting from creep and shrinkage, it is imperative to incorporate a bearing pad adjustment. Specifically, the adjustment is calculated as half of the temperature-induced shift, which, in this case, equates to 0.16 inches. By implementing a bearing pad, we aim to mitigate the structural impact of temperature variations and long-term deformations, ensuring optimal performance and stability of the bridge under varying environmental conditions. This meticulous consideration underscores the commitment to precision in engineering practices and the proactive measures taken to enhance the longevity and functionality of the structure.

References

1. AASHTO LRFD Bridge Design Specifications, 2012, Customary U.S. Units.
2. AASHTO. 1997. Guide Specifications for Design of Pedestrian Bridges, American Association of State Highway and Transportation Officials, Washington, DC.
3. AASHTO. 2001. Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 4th Edition, LTS-4, American Association of State Highway and Transportation Officials, Washington, DC.
4. AISC. 2005. Specification for Structural Steel Buildings, ANSI/AISC 360-05, American Institute of Steel Construction, Chicago, IL.
5. Bachmann, H. 2002. "Lively footbridges - a real challenge". Proceedings of the International Conference on the Design and Dynamic Behavior of Footbridges, November 20–22, Paris, France, pp.18–30.