Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 590–595

RTCEBE

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN : 2773-5184

An Investigation on Design and Analysis Overground Water Pipeline Steel Bridge

Muhammad Najiy Omar[1], Norwati Jamaluddin[2]*

[1]Faculty of Civil Engineering and Built Environment,
University Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe2022.03.01.071
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: The purpose for this project was to design an over ground steel pipeline bridge for water distribution network system. The work consisted of the determination of design parameters and the design of the superstructure of the bridge and a recommended construction plan. The final design of the over ground steel pipeline bridge is a Warren and Pratt truss bridge composed of a total 40 m and a width of 2 m span. The truss is made up of steel materials and I sections with both fixed end connections. The pipeline bridge is to be located at Terengganu for the project of Bekalan Air Kuala Terengganu. Next, for the aerial pipeline crossing supports a water pipeline with a diameter of 500 mm and a thickness of 30 mm. In the design of the superstructure, trusses were selected as the most suitable option amongst the possible bridge systems. Regarding our case study, a total of 3 load combination were used in this design and analysis which was ultimate limit strength (maximum), ultimate limit strength (minimum) and stress limit strength. While for the design loads, it can be determined from the Staad Pro results and the design of pile cap was designed using Staad Pro foundation software by inserting the reaction forces obtain from the analysis. A calculation for determine shear forces, bending and selection for the reinforcement of both design bridge after complete the analysis. Finally, from the analysis, we can have a total comparison value of both truss to choose the most suitable design to support the water distribution network system. It was found that the Warren truss was the perfect and suitable design that provided the most economical solution while meeting the deflection requirements specified by the pipeline designer.

Keywords: Over Ground Steel Pipeline Bridge, Warren And Pratt Truss, Load Combination

1. Introduction

In the structural engineering, truss is one of the important structure type for bridge design modelling. A truss is a system of triangular systems that are arranged and connected in such a way that they only experience axial force. These members are considered double-strength members because the force is applied only to both ends of the member, resulting in a force of pressure or tension. According to (Scheld, 1999), they are commonly used as bridge designs that givestheir ability to reach a long

Corresponding author: norwati@uthm.edu.my

distances efficiently. They also very strong, well-received and cost-effective option for building a variety of structure, for example in this case we want to design truss bridge for water pipeline through the watercourse in order to maximize structural efficiency which is often to measure in materials or manpower. There are many types of the truss structure based on their shape and layout such as, Warren Truss, Pratt Truss, K Truss, Fink Truss, Gambrel Truss and last but not least, Howe Truss. (Anlin, 1996)

2. Designs and methods

2.1 Design concept

At the concept design phase, the bridge with 40 m span length with width height 2 m and arrangement of the structure were determined. The diameter of the pipe is 1.5 m and the width of 2 m of the truss bridge. The height of the truss bridge is also 2m as this is a reasonable dimension for adequate clearance for both pipes. (Catbas & Frangopol, 2008)

2.2 Design loads

Permanent load that have used in this study as dead load is -1.68 kN/m and -3.05 kN/m. As for the variable load, the value that have used to design and analysis of the pipeline truss bridge is -0.76 kN/m. (Liren, 2005)

2.2.1 Factor of Safety (FOS)

In the design of truss bridge, ductile iron pipe and all the supports, the safety factor should be very common. It should be taken to measure the factor of safety.

2.2.2 Deadweight loads

Self-weight of truss bridge, carrier pipe, contents of carrier pipe, casing of pipe, isolation. Some of the unit dead weights widely used for pipe hanger design are as follows.

Table 1: Deadweight Loads (Wijaya, 2015)

Material	Usage	Unit Weight(kN/m3)
Steel	Truss, pipes, casing	80
Iron	Pipes	70
Concrete	Pipes, bridge elements	25
Lining	Internal pipe coating	Ignored
Water	Pipe content	15
Coating	External pipe coating	Include pipe unit weight

2.3 Software modelling

This bridge structure design model was run on Staad pro software. The bridge is modelled to perform analysis and support, deflection, and other reactions based on the parameters involved, and then it should be compared and evaluated between the two bridges that have been analysed at the end of the study.

Table 2: Summary of Model

Material Selection	Description
Steel	Bridge dimension :
UC305x305x97	Length : 40 m
UC203x203x46	Width : 2 m
CH300x90x41	Height : 2 m
Water	Top and bottom chord : 4 m
Coating	Web members : 4.47 m

2.3.1 Load combination

Table 3: Load Combination

Combination	Name	Primary	Name	Factor
3	Ultimate Limit Strength (Max)	1	GK	1.35
		2	QK	1.50
4	Ultimate Limit Strength (Min)	1	GK	1.35
		2	QK	1.50
5	Stress Limit Strength	1	GK	1.0
		2	QK	1.0

2.4 Pile caps design

Table 4: Design procedure

Data Procedure	Description
Axial Load	$250\ kN/each\ point\ load$
Grade of concrete	$30\ N/mm^2$
Grade of steel	$500\ N/mm^2$
Width of column	$500x500$
Diameter piles	$300x300$
Piles spacing	Min spacing = 900 mm
	Length = 3300 mm
Pile cap dimension	Width = 700
	Depth = 700
Weight of pile cap	$40.43\ kN$
Concrete cover	Cover = 75 mm

2.5 Shear resistance

Table 5: Shear resitance

V	$Vc1$	Vce
$135.16\ kN/mm2$	$400\ kN/mm2$	$766\ kN/mm2$

For the shear resitance, the value of V that have obtained from the software analysis is smaller than the value of the Vc1. Thus, it is safe and no shear reinforcement required.

2.6 Punching shear

Critical parameter, $P_m = 2\ x\ (\ b + h + 6\ x\ d) = 4.25\ m$

Table 6: Punching shear

V_{m1}	V_c	Description
$178.81\ kN/m^2$	$392.79 kN/m^2$	Safe!

Punching failure occurs on the inclined face of a truncated cone or pyramid, depending on the shape of the loaded area but for practical purposes, it is satisfactory to consider the perimeter of a rectangular failure.

2.7 Bending moment

Effective depth = 252 mm

Bending moment, $M_{ed} = 96.88\ kNm$

$K = 72.64 \times 10^{-6} < K' = 0.156$ Hence, Safe!

$z = 62.98 \leq 0.95\ x\ 252 = 239.4$ $\boldsymbol{OK}$!

3. Results and Discussion

3.1 Unity check for warren and pratt truss

Table 7: Comparison value of unity check

Warren Truss	Pratt Truss	Description
0.248	0.996	Both value < 1.0

A perform analysis of both propose type of bridge for warren and pratt truss, the both bridge gives the value of maximum ratio of the unity check below 1.0 which give all the members of those truss bridge did not have failure. Thus, warren truss design gives a smaller value of unity check ratio than a pratt truss bridge. So that, warren truss is the most suitable design to approve regarding the maximum unity check ratio due to the smallest value of the actual ratio. Both type of truss give a value of smaller than the maximum value of unity check which is 1.0. Hence, it is accepted.

3.2 Reactions

Table 8: Support reactions

Reaction force	Warren Truss (kN)	Pratt Truss (kN)	Description
Fx	288.20	92.05	ULS Max 1
Fy	240.26	237.38	ULS Max 1

The design's reaction value in each support of both designs is summarised in the table above. This is for ensure for the support that can satisfy all the equations of the equilibrium. It is also needed to provide good stability of the structure that provided by the rigid support. From the table above, it is shown that the warren truss design give a bigger value of reactions that can prove that the design is the most suitable for support the water distribution network system.

3.3 Internal forces

Table 9: Compression and tension value

Type	Warren Truss (kN)	Pratt Truss (kN)	Description
Compression	-240.264	-262.213	No failure
Tension	345.296	962.843	No failure

The maximum values at the first node of Warren truss design are -240.264 kN, it would mean maximum axial compression for this internal members. Next, for maximum axial tension it can be determine at the fifth node which state the value of 345.296 kN for this warren truss design. Hence, there is no failure obtain for all the members after complete the analysis. Therefore, it is acceptable.

Meanwhile, Pratt truss also give a maximum compression value for all of the internal members for the first node that give the value of -262.213 kN. For determine the maximum axial tension of the members for the Pratt truss, the sixth node give the value of 962.843 kN. Therefore, it is acceptable due to the no failure for all members of this Pratt truss design.

3.4 Discussions

In this section, the results of the study obtained from the analysis of the two bridges will unravel which design will be accepted and built for the purpose of channeling the piping system that has been discussed previously. First of all, the results will discuss in terms of the nature of the design that can be discussed in this session i.e. the number of truss members for the two types of bridge trusses.

According to the proposed design and analysis using StaadPro software, the Warren truss steel bridge has a total of 110 truss members and even the Pratt truss steel bridge also has the same number of truss members of 110. This shows that, these two bridges meet the economic taste in terms of cost and sustainability due to the number of members the same trusses as well as in terms of cost also have the same relatively high probability of being invested for construction purposes.

As for the deflection value that are obtain to have a criterion differences of these two types of truss bridges, we have to correlate the two deflection values obtained from the analysis system through staadpro software. Upon completion of the analysis, the results of the study found that the high value of pesogan found for the type of warren truss is 0.006 while for the type of pratt the value obtained is 0.007. This shows, the warren truss type has a slight advantage over the pratt truss type. In conclusion, through the analysis of this procedure we can determine with a design that can be built for the purpose of the pipeline with a design that is economical and sustainable in terms of durability and construction costs to be carried out.

4. Conclusion

In conclusion, this study have a complete discussion to do a full relationship among the total number of members and the deflection value for the both steel truss bridge that can carry water distribution network system. Hence, at the of the study, we have choose the best of the design model with a better in design with a sustainability criteria of the bridge structure.

5. Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Berman, J. W., Wang, B. S., Roeder, C. W., Lehman, D. E., & Olson, A. W. (2010). Triage evaluation of gusset plates in steel truss bridges (No. WA-RD 757.1). Washington (State). Dept. of Transportation.

[2] Brodniansky, J., Magura, M., & Slivanský, M. (2016). Increasing the Durability and Safety of Pipeline Bridges. Procedia Engineering, 156, 69-74

[3] Catbas, F. N., Susoy, M., & Frangopol, D. M. (2008). Structural health monitoring and reliability estimation: Long span truss bridge application with environmental monitoring data. Engineering Structures, 30(9), 2347-2359.

[4] Ketchum, M. A., Drouillard, F., & Scheld, J. (1999). Pipeline Bridge across the Arroyo Cangrejillo, Argentina. Structural engineering international, 9(1), 6-8.

[5] Guang-hua, C. A. I. (2010). Bracket and Truss Bridge Design of a Steelwork's Compositive Pipelines. Construction & Design for Project, (10), 15.

[6] Liren, G. X. Q. (2005). Application of Steel Truss Technique to Communication Pipeline in Striding over River. Telecom Engineering Techniques and Standardization, (1), 18.

[7] Mehrjoo, M., Khaji, N., Moharrami, H., & Bahreininejad, A. (2008). Damage detection of truss bridge joints using Artificial Neural Networks. Expert Systems with Applications, 35(3), 1122-1131.

[8] Wenli, S., & Anlin, Y. (1996). Statistical Analysis For Variable Loads Of Combined Arched Pipeline Bridge. Natural Gas Industry, (5), 05.

[9] Widjajakusuma, J., & Wijaya, H. (2015). Effect of geometries on the natural frequencies of Pratt truss bridges. Procedia Engineering, 125, 1149-1155.