

PAPER • OPEN ACCESS

## Comparative Study of Pratt Truss, Vierendeel Structure, and Plate Girder for Overhead Crane Girder

To cite this article: Mazin Abdulimam Ahmmed *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1090** 012058

View the [article online](#) for updates and enhancements.



**240th ECS Meeting** ORLANDO, FL

Orange County Convention Center Oct 10-14, 2021



Abstract submission due: April 9

**SUBMIT NOW**

# Comparative Study of Pratt Truss, Vierendeel Structure, and Plate Girder for Overhead Crane Girder

Mazin Abdulimam Ahmmed<sup>1</sup>, Mazen Dewan<sup>1</sup>, Hussein M. Ashour Al. Khuzaie<sup>2\*</sup>,

<sup>1</sup> Civil Engineering Department, College of Engineering, University of Basra, Iraq

<sup>2</sup> Civil Engineering Department, College of Engineering, Al-Muthanna University, Iraq

\* Corresponding Author: hma@mu.edu.iq

**Abstract.** This paper presents a study to get optimum type of crane girder. Three types of structures were studied: Pratt truss, Vierendeel frame and plate girder. Length of crane girder is 30 m and designed to carry 60 kN. Only (I) and angle steel sections were used to build crane girder. A nonlinear model was adopted to simulate the girder using finite element method. Weight of girder and maximum deflection were the main parameters used to compare. The results of the study identified that Vierendeel frame is the suitable type compared to the others to be designed and installed for this crane.

## 1. Introduction

A crane is an equipment constructed on work space such as workshops and warehouses for lifting and lowering heavy masses. It is also used in the transportation industry for loading and unloading freight cargo. The crane is mainly constructed as a machine that is capable to achieve these tasks safely. This machine assembled on girder beam and furnished with various accessories (wire rope, sheaves, and winder) to be able for finalizing its task in well state [1].

The girder beam transfers the load and its strength should be assessed. This girder designed as double girder and analysed [2, 3]. On other hand it may be a single beam [4].

For auto workshops (lightweights), a single girder usually used to be simple in design and manufacturing [5]. Steel sections are the usual materials used for design and assembly the gantry crane [2-4].

A numerical analysis carried out on a portal gantry crane of box section, using a finite element model. The analysis was done to determine equivalent stress experienced by the beam of crane, considering the effect of the shape and the location of the applied loading [6].

Shell elements model has been utilized for analysing the girder beam of an overhead bridge crane. This analysis carried out for determining the best size of steel sections of the girder that can resist both tensile stresses and deformation. COSMOS software was used for this purpose. By adopting the theory of modifying energy (von Misses' theory), the maximum tensile stress was calculated. It was found two critical areas of stresses within the entire body of the girder beam. These two locations of stresses cause vulnerability, so bearing capacity of the structures should be enhanced to increase the solidity of this girder [7].

A crane was designed for services in rubber tires warehouse analysed utilizing a new model of finite element method. The stress and deformation developed in the crane girder was evaluated as well as the buckling of the crane legs was investigated. ANSYS and Autodesk INVENTOR 2010 software were



used to perform this analysis. The results of stress, deformation and buckling agreed with that of the conventional calculations. It was found that the developed stress was under the yield strength of steel materials [8].

A Multi axial fatigue that was developed by the wheel load and block rail of a crane was investigated. The crane girder was installed by fillet welding. The induced stress by the point load at the top fiber of the girder including local stress components was checked. For the purpose of this investigation, two crane runway girders were modelled. Flexural bending moment and point wheel load were applied on these two girders simultaneously. According to the results of this study, it was found that the amplitude of the stress components did not occur at the same time, while the induced shear stress alters its direction to give a control on the initiation of the crack in the elements of the girders [9].

As reviewed in the above, it is obvious that there are various types of crane girder structures may be designed along with different methods of analysis i.e., no restricted rule to be followed for obtaining an ideal or best structure designed and fabricated for overhead crane girders. This fact is due to different capacities and numerous space spans of cranes.

This study tries to analyse three common types of crane girder, which are: 1) Pratt truss, in which the chords transfer the bending moment while its struts carry shear forces; 2) Viernedeel frame that is created by rectangular and trapezoidal panels, i.e., no diagonal members and 3) plate girder which is constructed from I-sections fabricated from separated structural steel plates. The main purpose of the current investigation of the chosen three types of girders is to obtain the suitable one among these three types for design a girder of span length equals 30 m and be able to carry a load 60 kN. For carrying out the study, a nonlinear modelling applied to these three kinds of girder using finite element method. Parameters such as bending moment, shear force, weight and deflection of each type would be determined. Upon the results of these parameters, it may decide to select the suitable type of the girder that may be designed with capacity 60 kN and be efficient for span 30 m.

## 2. Modelling

A finite elements analysis was performed by Staad pro V<sub>8</sub> software [10]. FRAME element was adopted to simulate axial force, torsion, and bending effects for all elements of the structures. In modelling, each element is a line that connects two points. Each element has six degrees of freedom, three directional translations in x, y, and z axes, and three rotational displacements about x, y, and z axes.

### 2.1 Materials and details

Three girders were designed to carry the load in this study (Pratt truss, Viernedeel frame and plate girder). All girders are of span 30m. The girder is modelled and analysed using Staad pro V<sub>8</sub> software. The design of the steel structure was done according to [11]. For dead and live loads that were applied to the structure, the standards [12] and [13] were used, respectively. The dead load includes the weights of materials and the live load was 60 kN. Steel is used in modelling of beams and bracing members. The steel properties were presented in Table (1). The three types of crane girder were drafted along with their section in figures (1-3), Pratt truss, Vierendeel truss, and plate girder, respectively.

**Table 1.** Steel properties

Item	Description	Unit	Value
$f_y$	Minimum yield stress	N/mm <sup>2</sup>	250
$F_u$	Ultimate tensile stress	N/mm <sup>2</sup>	410
$E_s$	Modulus of elasticity	N/mm <sup>2</sup>	210000
$\rho_s$	Density	kN/m <sup>3</sup>	77
$\nu_s$	Poisson's ratio	---	0.3

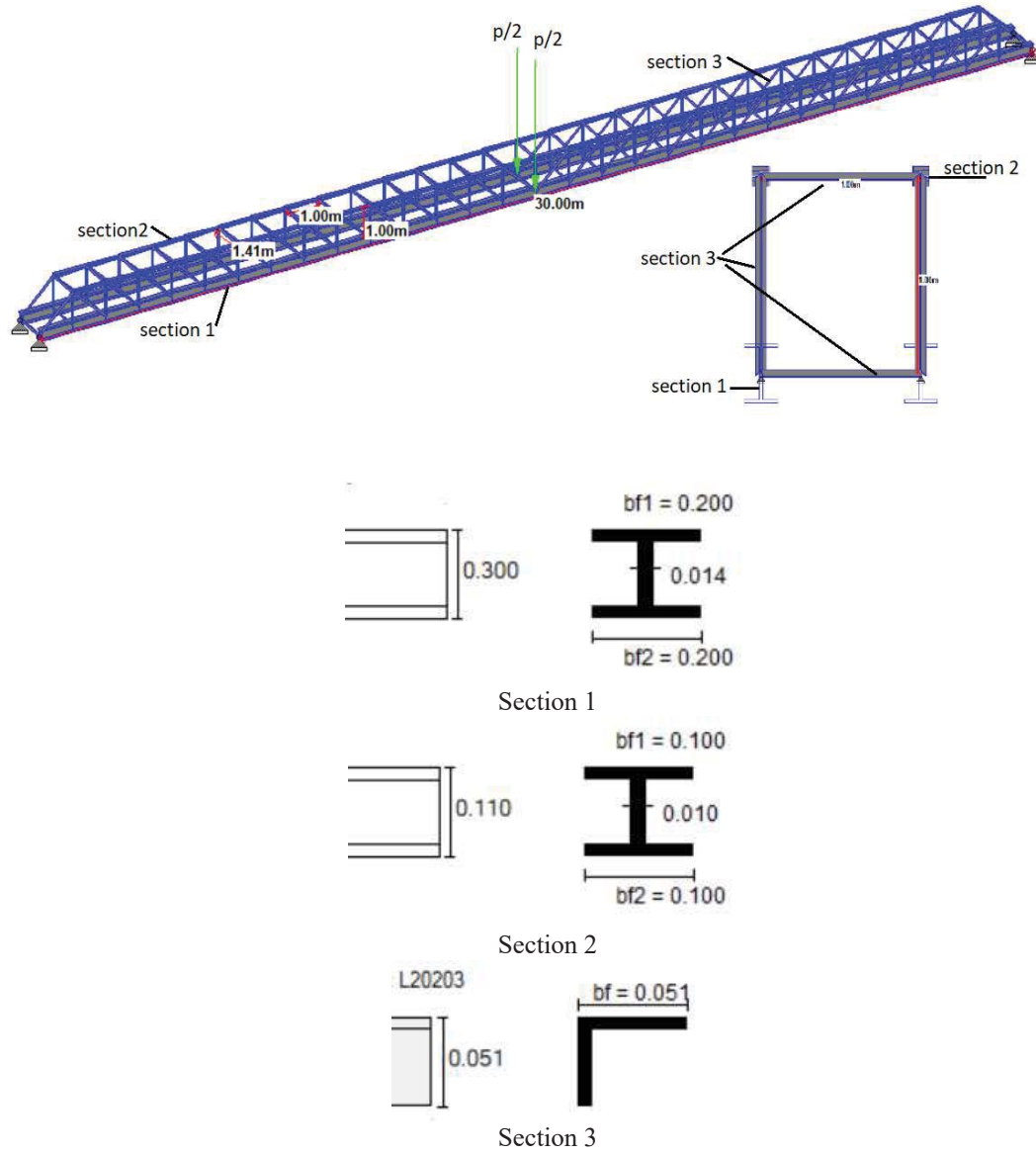


Figure 1. Pratt truss

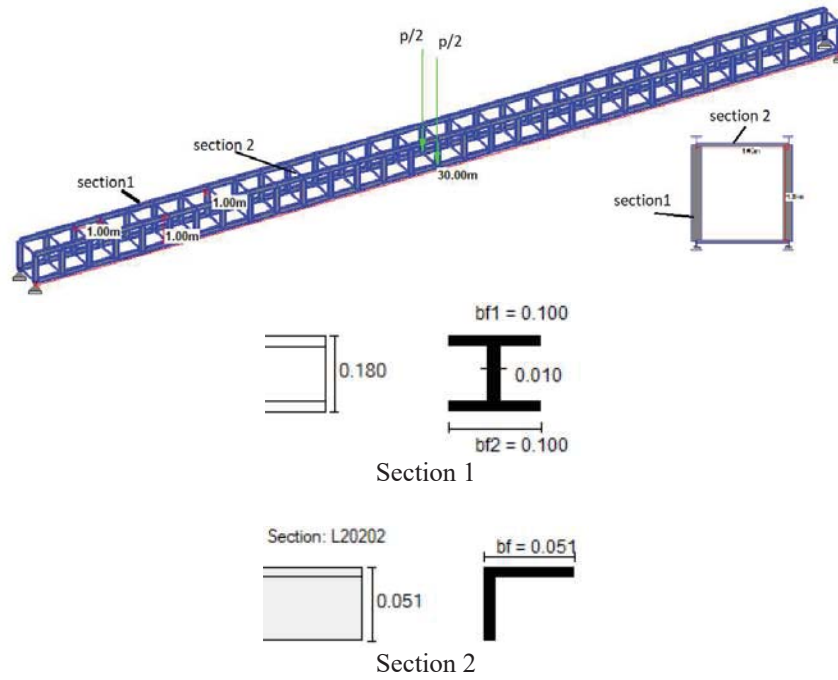


Figure 2. Viernedeel Frame

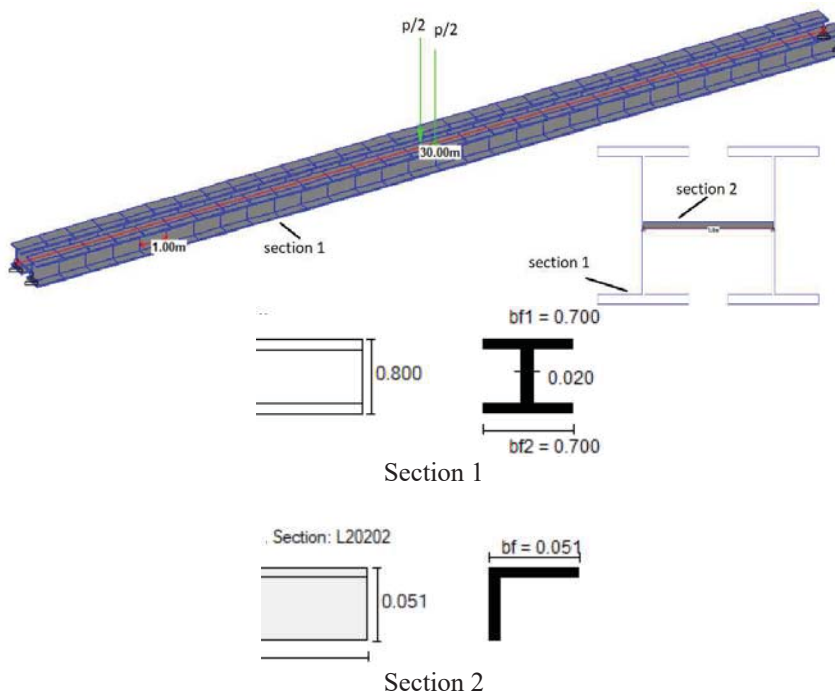


Figure 3. Plate Girder

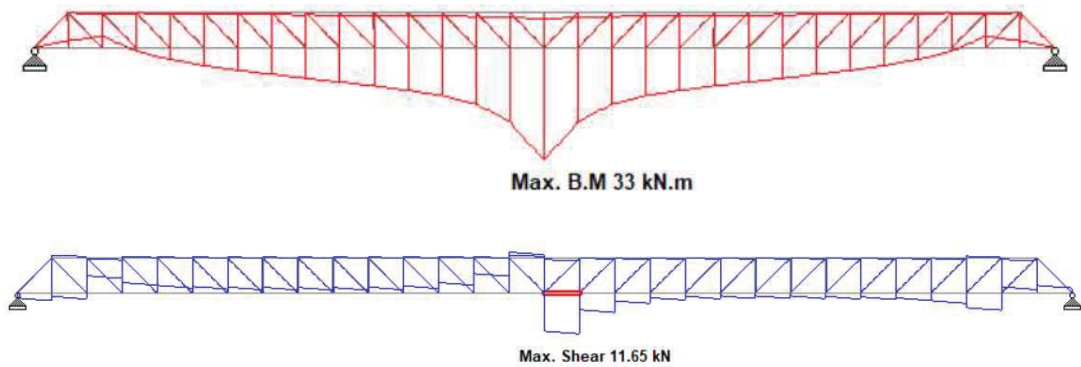
**3. Results**

In this study, two steel sections were used (I) and angle sections only in design of the three types of crane structures considered, which were: Pratt truss, Viernedeel and plate girder.

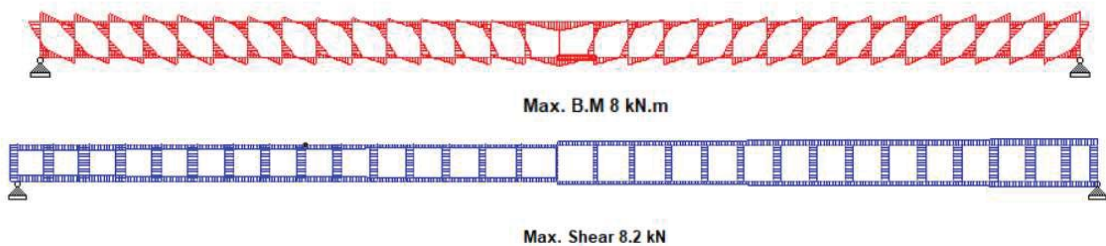
The results of the maximum bending moment, the maximum shear force and the weight of the three types showed variation in values among the three types, while the deflection is slightly different. This may attribute to the different geometry of each type.

Figures (4-6), present the bending moment and the shear force diagrams of Pratt, Viernedeel and plate girders, respectively.

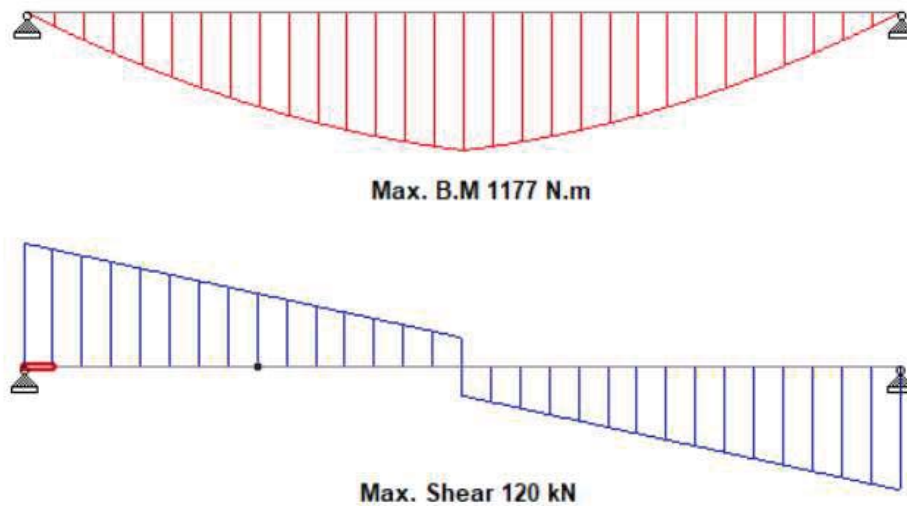
It was found the maximum bending moment and shear force for Pratt truss 33 kN.m and 11.7 kN, respectively; while that for Viernedeel frame were 8 kN.m and 8.2 kN respectively, and that for plate girder type were 1177 kN.m and 120 kN respectively.



**Figure 4.** Bending Moment and Shear Force for Pratt Truss



**Figure 5.** Bending Moment and Shear Force for Viernedeel frame



**Figure 6.** Bending Moment and Shear Force for Plate Girder

The weight and maximum deflection of each girder were presented in table (2). It was found that the weight of the three types of girder differs for each among the others. It was found the weight of Pratt truss is more than that for Viernedeel girder by about 18%, on the other hand, the weight of the plate girder type is more than that for Viernedeel type by 273%. Regarding the maximum deflection for Viernedeel frame, Pratt truss and plate girders, it was approximately the same. The lowest value of the maximum deflection was for Viernedeel type. So that, it may be concluded that Viernedeel frame is optimum girder to lift heavy weight and more suitable for design for crane girder of 30m length and of 60 kN capacity. In addition to that, practically, Viernedeel type is easier to fabricate and install because of its simplicity of geometry. This leads to consider this type of crane girder as the suitable kind, that minimizes the time and effort, so, the cost will decrease.

**Table 2.** Weights and Deflections of girders

Type of girder	Weight, kN	Maximum deflection, mm
Pratt truss	65	70
Viernedeel frame	55	67
Plate girder	205	68

**4. Conclusions**

The main aim of this work is to obtain the suitable crane structure for span length of 30 m and 60 kN load among three types which were chosen: Pratt truss, Viernedeel frame, and plate girder. Depending on different parameters which were, the maximum bending moment, the maximum shear force, the weight and the deflection for choosing the suitable one. The following points can be extracted from this investigation:

- It was found that Viernedeel frame was of less weight among Pratt truss and plate girder.



- The deflection was nearly equal for all three types of girder, while the other parameters (the maximum bending moment and the maximum shear force) are different and may compare between the studied types to decide the optimum girder to carry heavy load.
- Vierendeel girder joints are easy to construct as all members are joined perpendicularly whereas in case of truss girder of members takes place hence tedious job for installation.
- Modifications and maintenance are easy for Vierendeel girder.

There for it can be concluded that, for 30 m space and 60 kN crane girder, the optimum structure is Vierendeel frame.

## 5. References

- [1] A. Suratkar, V. Shukla, and K. S. Zakiuddin "Design optimization of overhead EOT crane box girder using finite element analysis", *Int. J. Engineering Research Tech. (IJERT)*, pp. 2278-0181, 2013.
- [2] B.C. Alkin, C.E. Imrak, and H. H Kocabas, "Solid modeling and finite element analysis of an overhead crane bridge". *Acta Polyt.* vol.45(3), pp. 61-67, 2005.
- [3] C.B. Pinca, G.O. Tirian, A. Josan, and G. Chete, "Quantitive and qualitative study on the state of stresses and strains of the strength structure of a crane bridge". *WSEAS Tran. Appl. Theor. Mech.* vol. 5(4), pp. 231-241, 2010.
- [4] L. Sowa and P. Kwiaton, "Numerical analysis of stress fields generated in the gantry cranebeam". *Procedia Eng.* Vol. 177, pp. 218-224, 2017.
- [5] D. Gaska and T. Haniszewski, "Modeling studies on the use of aluminum alloys in lightweight load-carrying crane structures". *Transport Problems.* vol.11(3), pp. 13-20, 2016.
- [6] S. Leszk S.Tomasz and K. Pawel, "The effect of the gantry crane beam cross section on the level of generated stresses". *EJD Science*; vol. 157(4), 2018.
- [7] C.B. Pinca, G.O. Tirian and A. Josan, "Application of finite element method to an overhead crane bridge", , vol. 4 (2), 2009.
- [8] I.Gerdemeli, S.Kurt and M. Metinyıldırım, "Calculations, modeling and analysis with finite element method of rubber tyred container stacking crane", 14th International Research/Expert Conference, Trends In The Development Of Machinery And Associated Technology, 2010.
- [9] M. Euler and U. Kuhlmann, "Crane runways - Fatigue evaluation of crane rail welds using local concepts", *International Journal of Fatigue*, 2011.
- [10] Staad pro V<sub>8</sub>, Manual.
- [11] Indian Standard Code, IS 800: General Construction in Steel - Code of Practice, 2007.
- [12] Indian Standard Code, IS 875-1 Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures, Part 1: Dead Loads - Unit Weights of Building Material and Stored Materials, 1987.
- [13] Indian Standard Code, IS 875-2 (1987): Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures, Part 2: Imposed Loads.