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TABLE OF CONTENT

ELECTRICAL AND INFORMATICS ENGINEERING

Analysis of Stress and Deformation of Cantilever Steel Beam T Section and Half IWF Section Using Finite Element Method

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Abstract

Beams is one of structural element which hold bending load and shear loads that are more dominant that axial load. The supports of beam are also very diverse, one of which is cantilever beam. Cantilever beam is a beam that has fixed support at one end and free at the other end. Cantilever beam can be made from many of materials, one of which is steel section. Its light weight and have a large enough strength, and made by fabrication so it has a isotropic material making easier to be applied as a beam structure. But cantilevered structure that has bigger number of internal forces toward its fixed supports, causing usage of uniform steel section becomes less optimal. Therefore, it will be investigated stress and deformation T section steel beam with uniform cross-section with half IWF steel section with diagonal cut so it has non-prismatic section when used as a cantilever beam. In this study, samples are eight different dimension with four couples with the same load to the T section and IWF section and had a comparable size. Analysis is held by using finite element method in a computer program that are freeware, whic are FreeCAD as a 3D drawing program and LISAFEA as calculation program. The result showed that comparable size, the use of half IWF sections with diagonal cut are more efficient looked by the minimum of stress and deformation than uniform T section steel beam.

Keywords: analysis of stress and deformation, short span cantilever beam, IWF and T section beam, finite element method

1. Background

Beams is one of the most important structural element in buildings. The bending loads and shear forces that received by beam are more dominant than the axial force [Priyosulistyo, 2010]. Generally forces toward beam are perpendicular to main axis of the beam. There are many types of beam based on the supports, one of which is cantilever beam. Cantilever beam is beam with fixed support at one end and free at the other end. This type of beam are often used in buildings and bridges that supporting load directly exposed to the outside environment, such as edge of roof, air conditioner engine mountings on buildings, and inspection way on a bridge.

Cantilever beam can be formed from many of materials, one of which is a steel section. It has several advantages, for examples it is a light-weight structures, has a large enough strength, and since steel section is formed from fabrication, steel section is easier to be applied as a beam structure. Here is presented in Figure 1 is an example of using a steel cantilever beam on a railway bridge on Suprapto Street, Yogyakarta. These beams form by

IWF section with non-prismatic type.

However, directly usage of uniform cross section steel beam as cantilever structure considered less than optimal, because the value of internal forces (bending and shear forces) is bigger toward its fixed supports. Therefore in this study, value of stress and deformation that occur in the steel cantilever beam will be compared. For equal and fair comparison, samples were taken in the form of T section which represents steel beams with uniform section and a half IWF section with diagonal cuts as representations steel beam section with more optimal use of materials.

By this research, it is expected to know the comparison of two form types of beams and know which section is more optimal so that in the end, people can apply directly in the field and can be applied in the industry of construction in general.

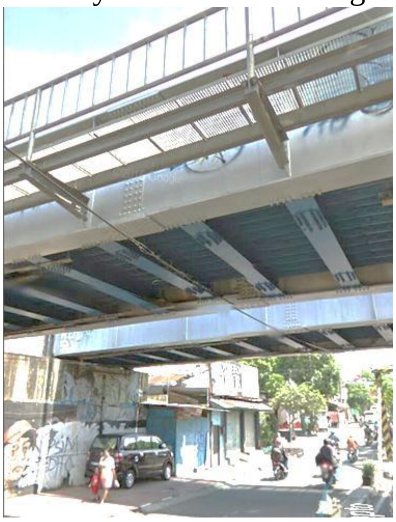


Figure 1. Examples of steel usage as inspection way at briges in Yogyakarta

2. Literature Review

Some research on steel cantilever beam have been done before. One among them is conducted by Sim and Uang (2011). Their research conducted on welds on steel cantilever beam retaining structure functioned as street signs. In this study, a steel pipe connections are studied to be designed because the connection is quite vulnerable to failure on cantilever structure. The analysis using ABAQUS in 2005 which based on finite element method. The results showed some failures in welded joints due to cantilevered structure as a result of wind load that applied, and this study also proposed alternative welding connection at the fixed support of cantilever.

Szychowski (2015) conducted a review of stability of the wall structure formed by thin steel cantilever. This study was conducted using samples of steel with spans up to 60 cm, width 10 cm, with steel thickness of 2 mm. The result of this study is value variatons of plate buckling coefficient (k) resulting from stress analysis calculations.

In addition to the above two studies, research ever conducted by Fazelzadeh and Kazemi-Lari (2014) concerning the high cantilever beam stability analysis with distributed load. Beams can be either steel or other isotropic material. In this experiment, a beam with a very thin thickness and given perpendicular load towad main axis of beam. From these results, it is known that the numerical analysis and with the added of load in the beam will cause instability either a static or dynamic.

It has been much research done to examine the cantilever beam along its variations, but as far as known, research on comparative analysis of stresses and deformations T beam steel section with half IWF section has never been done before.

3. Methods of Research

This research was done in various ways to get the stress and deformation values that will be compared. The entire programs that are used are freeware. Three-dimensional beam are drawed using FreeCAD program and analysis was performed using the finite element method by LisaFEA. Samples which used are T section and IWF section of steel beam These following are the explanation about the material used and the methods used.

3.1. Samples

The test object is generally consist of two types, which were steel T section and IWF section. Yield strength of steel that used is 400 MPa, elastic modulus (Young's modulus, E) amounted to 200.000 MPa, density of steel amounting to 7850 kg / m3, value of Poisson's ratio is 0.3, with the entire span remains that short span of 1.5 m. The following Table 1 is a summary of section of steel beam that are used as samples

Table 1. All samples that are used in this research

No	Steel section	H_{start} (mm)	H_{end} (mm)	t_1 (mm) *flange*	t_2 (mm) *web*	Weight (kg/m)	Load Applied (kN)
1	½IWF 150x75x5x7	30	120	5	7	14.00	0.50
2	T 75x75x5x7	75	75	5	7	8.93	
3	½IWF 200x100x5.5x8	30	170	5.5	8	21.30	0.75
4	T 100x100x5.5x8	100	100	5.5	8	13.58	
5	½IWF 250x125x6x9	30	220	6	9	29.60	1.00
6	T 125x125x6x9	125	125	6	9	18.83	
7	½IWF 300x150x6.5x9	30	270	6.5	9	36.70	1.25
8	T 150x150x6.5x9	150	150	6.5	9	23.39	

Steel profiles that are used have different characteristics, which is on the cross section type. For T section, uses T section with cross-sectional area does not change, or it can be called a uniform. Unlike the T section, the used of IWF section cut into two parts with diagonal cuts, which meant that both ends have different cross-sectional area, resulting in non-prismatic cross-section. The applied load is equal to the size of a comparable profile, but it is increased, depends on cross-sectional area of each types. Below in Figure 2 is a three-dimensional illustration T section and IWF section that analyzed and compared in this study.

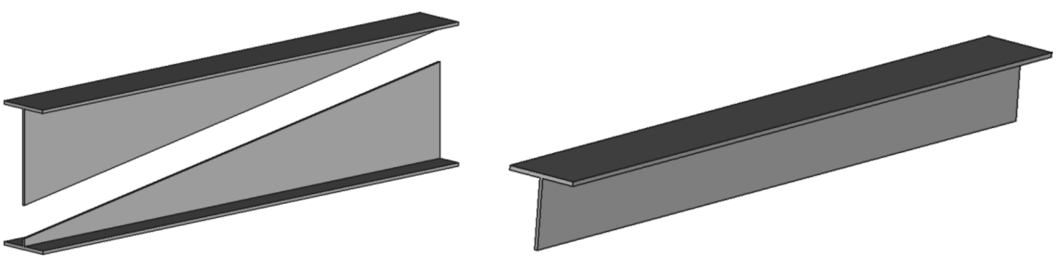
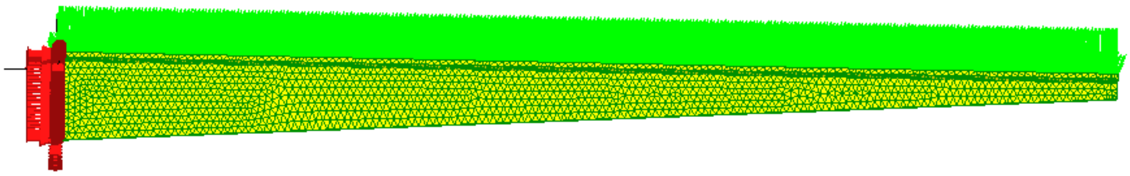


Figure 2. Illustration of half-IWF section and T section steel beam that used in this study

3.2. Methods

In this study, analysis of stress and deflection on the beams which are reviewed using LISAFEA 8.0 and the draw of 3-dimensional model using FreeCAD. Both of them are a program that is free to use (open source) and the software has been verified by researchers using simpler specimen, the resulting value is not far from the calculation of the analysis manually.

Support of samples in this research is cantilever type, which is fixed at one end and free at the other end. At the fixed support, the value of displacement and rotation value is zero. Load is given according to Table 1 and the loading is done evenly on the surface of the beam
as a distributed load. Here in Figure 3, given an illustration of loading and support of samples.



Fixed supported　　Distributed load　　Sample of cantilever beam

Figure 3. Illustration of loading and support of samples

1, shown in the formula used in the analysis of von-Mises yield criterion (Srinath, 2009).

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2 = 2\sigma_y{}^2 \quad (1)$$

with :

σ_1 = Stress in axis 1

σ_2 = Stress in axis 2

σ_3 = Stress in axis 3

σ_y = von-Mises stress

4. Results and Discussion

This research was carried out by describing the specimen 3-dimensionally on FreeCAD and perform geometry on LisaFEA program to do the stress and deformation analysis. A total of four pairs of the specimen, which is 4 pieces of sample cross section of IWF and 4 pieces of sample cross-section of T section with 1.5 m span given load varies, from 0.5 tons to 1.25 tons, depending on the size of its cross-section.

Prior to the overall analysis, first it must be determined number of elements that will be used for each test specimen in finite element method. The smaller elements are used will resulting more detailed and precise calculation process on the computer but would take longer time, and vice versa when used large-sized elements. Therefore, it is conducted the calculation of convergence in the analysis of the finite element method for the selection of the size of the element, so that when the size of these elements can be used effectively by the time calculation process and the resulting value of fixed precision. Analysis was conducted on one specimen by changing the size and number of elements

that are used with the given load remains/static and compared the displacement results. The following Table 2 presented the results of convergence has been done in the analysis process. From the analysis of convergence, it is known that the use volume element of 20-80 mm^3 has resulted fairly stable value, so in this study a maximum volume of an element in the process of meshing is used by
20 mm^3.

Table 2. Result of convergence analysis in finite element method

Volume of element (mm^3)	Number of element	Displacement (mm)
500	777	25.17
200	790	25.13
100	892	25.00
80	888	24.99
60	1007	24.99
40	1433	24.99
20	3761	24.99

After convergence analysis is done, stress and deformation analysis on samples conducted and the value of von-Mises stress and the resulting displacement are recorded and calculated difference between results of a cross-sectional half IWF and T section. The results of the analysis and the comparison is shown in Table 3 and shown in Figure 4 as a comparison chart.

Table 3. Result of stress and deformation analysis of samples

No	Sections	Load (ton)	Max. stress of von-Misses (MPa)	Δ (mm)	Differences of stress (%)	Differences of displacement (%)
1	½IWF 150x75x5x7	0.5	374.70	12.50	83.24	100.32
2	T 75x75x5x7		686.60	25.04		
3	½IWF 200x100x5.5x8	0.75	269.30	6.66	120.61	111.26
4	T 100x100x5.5x8		594.10	14.07		
5	½IWF 250x125x6x9	1	197.20	4.04	144.32	115.35
6	T 125x125x6x9		481.80	8.70		
7	½IWF 300x150x6.5x9	1.25	128.80	2.73	215.53	115.33
8	T 150x150x6.5x9		406.40	5.89		

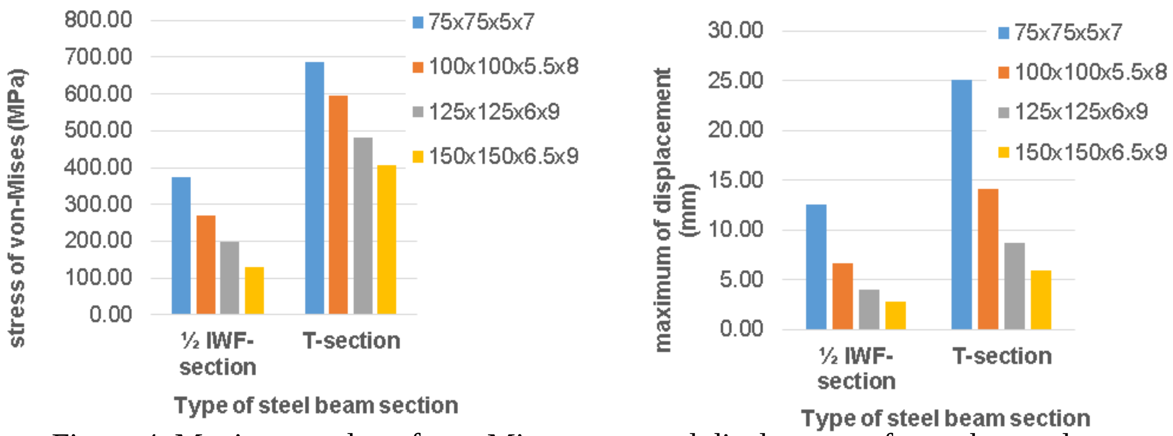


Figure 4. Maximum value of von-Mises stress and displacement for each samples

In addition to the value of the comparison results of stress analysis and deformation, it is known the distribution of stress in the specimen. Here in Figure 5 and Figure 6, is shown stress distribution occurs in the test object with a cross-sectional IWF and the T. From the analysis, it is known that the distribution of the compressive stress occurs in the upper surface and a tensile stress occurs on the surface area below. It is caused by a support provided in the form fixed support and loading is done from the top surface toward the bottom (gravity).

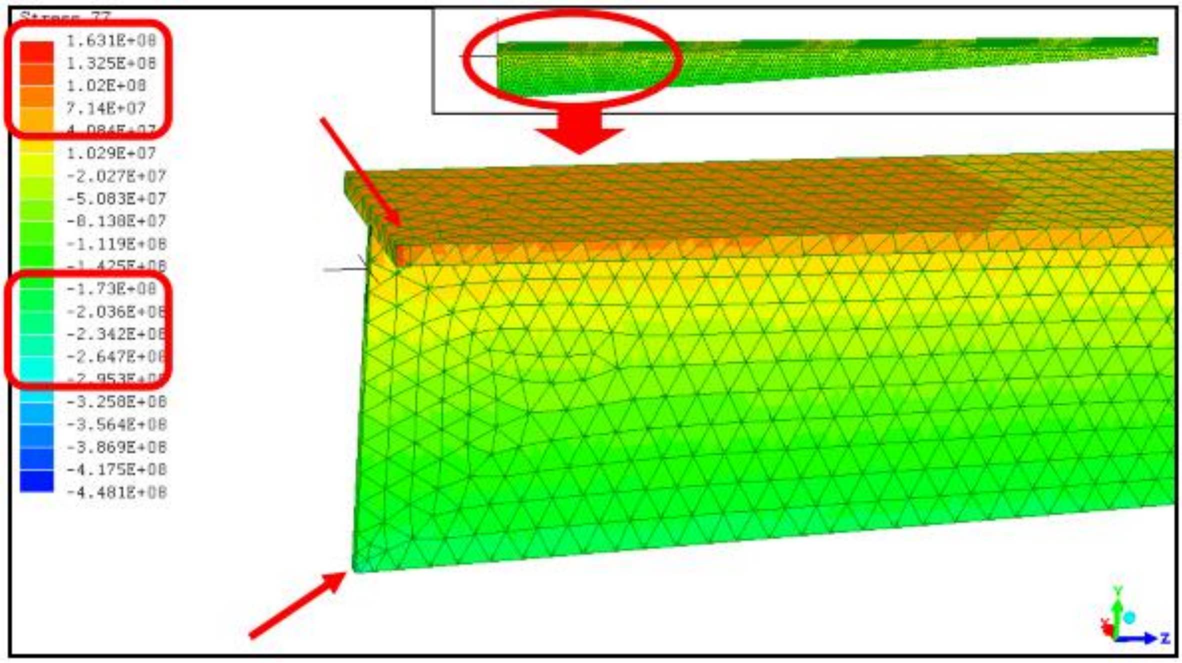


Figure 5. Stress distribution on half-IWF section steel beam

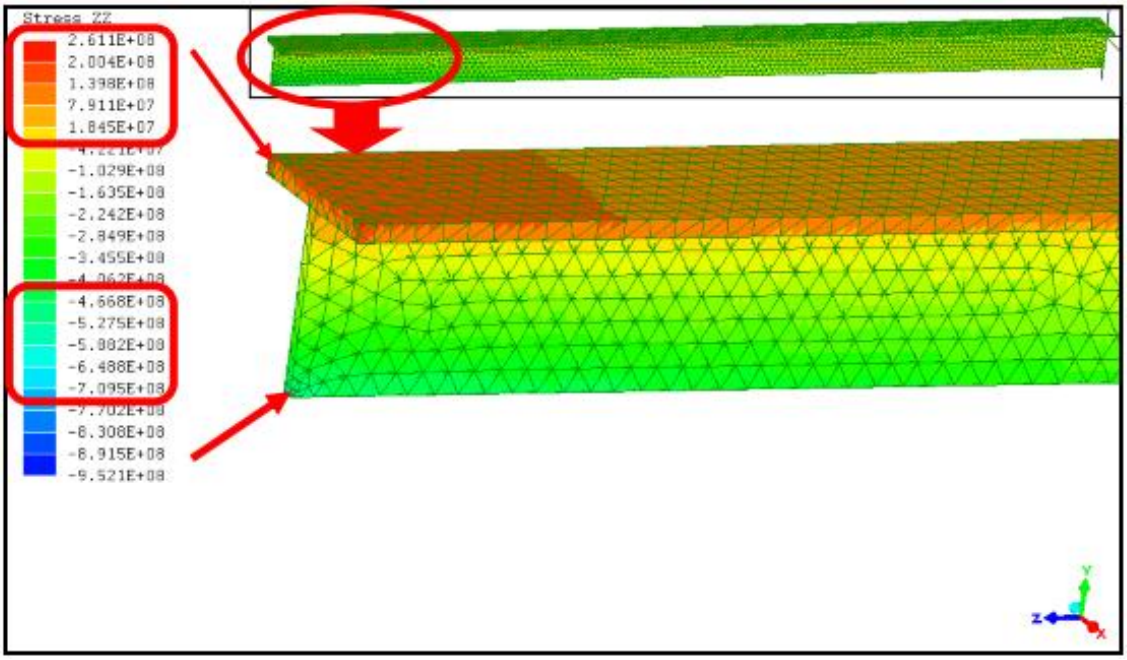


Figure 6. Stress distribution on T-section steel beam

4. Conclusion

From the research that has been done above, it can be concluded in general that uses of half cross-section of IWF section is more effective when used for a short span cantilever structure compared with T cross section seen from the result of stresses and deformation analysis. In addition, the stress distribution occurs in a cantilever beams are divided into two type, which are a tensile stress on the surrounding area of loading surface and compressive stress occurs in the lower surface of the beam.

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