Numerical and analytical investigation of steel beam subjected to four-point bending

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Abstract. A One type of bending tests is four-point bending test. The aim of this test is to investigate the properties and behavior of materials with structural applications. This study uses numerical and analytical studies. Results from both of these studies help to improve in experimental works. The purpose of this study is to predict steel beam behavior subjected to four-point bending test. This study intension is to analyze flexural beam subjected to four-point bending prior to experimental work. Main results of this research are location of strain gauge and LVDT on steel beam based on numerical study, manual calculation, and analytical study. Analytical study uses linear elasticity theory of solid objects. This study results is position of strain gauge and LVDT. Strain gauge is located between two concentrated loads at the top beam and bottom beam. LVDT is located between two concentrated loads.

1. Introduction

Four-point bending test is one of the most common material testing procedures for investigating the properties and behaviour of materials with structural applications. It has also been realized that the real behaviour of steel beam subjected to four-point bending not only the specific performance of four-point bending but also the overall structural response. In order to get structural response, the application of measurement tools such as strain gauge and Linear Variable Displacement Transducer (LVDT) are practically important.

In this paper, a suitable location of strain gauge and LVDT measurement tools for a steel beam subjected to four-point bending were investigated by using numerical and analytical studies. Results of numerical and analytical studies help to improve in experimental works. Numerical and analytical studies prior to experimental studies have been conducted by [1], [2], [3], [4]and [5]. They have conducted experimental investigations, distribution of stresses and displacements of cold formed thin-walled beams. Based on these studies, study by [6] investigates the behaviour of web crippling of cold-formed steel lipped channel beams subjected to end-one-flange (EOF), interior-one-flange (IOF), end-two-flange (ETF), and interior-two-flange (ITF). Study by [6] tested 48 cold-formed steel lipped
channel beams considering different boundary and loading conditions, bearing lengths and section heights.

The beam, which consider to be used in this presented paper, is simply supported and subjected to pure bending. [7] is used as a reference for four-point bending test. The distance of two concentrated loads is one third of support span. The main outcome of this study is the placement of strain gauge and LVDT on steel beam based on the numerical results and analytical analysis.

2. Methodology
This study used numerical and analytical study. Figure 1 presents the methodology in this study. It is assume that each concentrated load, which is applied on the steel beam, is 100 tons. Profile of steel section is IWF. Figure 2 shows a cross-sectional IWF profile steel beams. Height of IWF profile is 200 mm. Width of IWF profile is 150 mm. Thick of wings and web are 9 mm and 6 mm, respectively. These measurement are based on table of Gunung Garuda, condition of the furnace in PusLitBangKim Cileunyi Bandung, and [7]. According to [7], the proportion of the height of beam to the length of beam is 16: 1. The length of the beam, that can be burned in furnaces located in Bandung Cileunyi PUSKIM, is 3800 mm.

![Study method diagram](image-url)
3. Results and discussion
Isotropic and solid material, that confirms to the Von Mises yielding criterion. Young’s modulus E, and poisson ratio are used in modeling the materials. Assumptions used in this study are $E = 200.000 \text{ MPa}$, and Poisson’s ratio $\nu = 0.3$. The commercial FEM analysis used in this study is ABAQUS 6.14.5

The beam uses linear elasticity as the simplest form of elasticity available in Abaqus [8]. Isotropic material behavior is defined in this linear elastic model. Isotropic material behavior is valid for small elastic strains [8]. To ensure smooth deformation in the modelling, the model was discretized using linear hexahedral. Steps in this model are initial and final step. Boundary condition is in initial step. Meanwhile, loads are in final step. Two concentrated loads with the same magnitude are placed on the one third and two third of the beam length. Figure 3 to Figure 5 presents the stress occurs in the beam.
Figure 4. Stress occurs at the beam after two concentrated loads applied.

Figure 5. Stress occurs at the beam before and after two concentrated loads applied.
Figure 6. Moment and shear from manual calculation at beam with two concentrated loads.

Figure 6 shows that positive moment occur on the beam with two concentrated loads. The bottom side of the beam section has tension moment. On the other side, the upper side of the beam section has compressive moment. Strain on the bottom side of the beam section is tension strain. Meanwhile, strain on the upper side of the beam section is compressive strain. The same result appears by using finite element method. In this study, Abaqus version 16.4 is used as finite element method program. Strain gauge position, which will be placed between two concentrated loads at upper side and down side of beam section, is based on manual and numeric calculation. Figure 7 presents strain gauge location based on manual and numerical calculation.
Flexural beam element analysis, that uses linear elasticity theory for solid objects, gives exact solution. In case of primary beam axis as shown in Figure 8, it gets Equation (1).

\[ M_0 = \int_A z\sigma_{xx} dA \]  \hspace{1cm} (1)

In Equation (1), A is beam section area. Stress component \( \neq 0 \) is in Equation (2):

\[ \sigma_{xx} = \frac{M_0 z}{I} \]  \hspace{1cm} (2)

Deflection component at Equation (3) comes from Hooke law.
\[ w = \frac{M_0}{2EI} [-vz^2 - x^2 + vy^2] \] (3)

In Equation (3), Figure 4, Figure 5, and Figure 6, the biggest value of moment places is located between two concentrated loads on the steel beam. Based on this result, position of LVDT is between two concentrated loads. Figure 9 shows position of LVDT.

4. Conclusion
This study analyzes flexural beams by using numerical and analytical method. The intention of this study is to predict strain and deflection of steel beams subjected to four-point bending. Earlier prediction regarding strain will be used to place strain gauge on the beam. In addition, previous prediction regarding deflection is used to place Linear Variable Displacement Transducer (LVDT). Strain gauge and LVDT location in this study:
1. Strain gauge is located between two concentrated loads at the top beam and bottom beam.
2. LVDT is located between two concentrated loads.

5. References
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