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<https://jurnalteknik.unisla.ac.id/index.php/CVL>
<https://doi.org/10.30736/cvl.v2i2>



Analysis of the Center of Gravity and Moment of Inertia of Concrete Beam and Column Cross-Sections Using Manual and AutoCAD Methods in a Simple Building: the Barracks of Infantry Bengkulu

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ARTICLE INFO

Article History :

Article entry : 04-07-2026

Article revised : 23-07-2026

Article received : 07-08-2026

Keywords :

AutoCAD, Concrete Beams and Columns, Manual Method, Moment of Inertia, Center of Gravity.

IEEE Style in citing this article :

Nazmi Aprilla Wibowo and Simon Petrus Hamonangan Simorangkir, "Analysis of the Center of Gravity and Moment of Inertia of Concrete Beam and Column Cross-Sections Using Manual and AutoCAD Methods in a Simple Building: the Barracks of Infantry Bengkulu", *CVL*, vol. 11, no. 2, pp. 278–293, Sep. 2026.

ABSTRACT

Concrete beams and columns are important structural elements that support the strength, stability, and safety of a building. This study aims to compare the centroid and moment of inertia of concrete beam and column cross-sections calculated using manual methods and AutoCAD in the Barracks D project of the 847th TP Infantry Battalion in Bengkulu. This study uses a descriptive comparative method. The analysis was conducted on cross-sections in the support areas, namely B1–K1 and B2–KP, and in the field areas, namely B1, B2, and K1. AutoCAD modeling was carried out using Polyline, Region, and Massprop commands to determine the geometric properties of each cross-section. The results show that the field-area cross-sections have very similar results between the manual and AutoCAD methods. The difference in centroid coordinates was 0.00%, while the moment of inertia deviation was very small, approximately 0.00000004%. However, larger differences were found in the support areas. The X-coordinate differences were 58.58% and 64.29%, while the Y-coordinate differences were 33.28% and 40.00%. The moment of inertia differences were 4.32% and 4.01%. The manual method provides detailed calculation steps but requires more time. AutoCAD is faster and more efficient, especially for complex cross-sections. However, its accuracy depends on the drawing data and only represents gross cross-sectional geometry.

1. Introduction

Structural components are crucial for ensuring the strength, stability, serviceability, and safety of a structure in construction projects. Reinforced concrete beams and columns are among the most commonly used elements in structural engineering [1]. Concrete beams primarily resist bending moments and shear forces, while concrete columns act as the main vertical elements that transfer loads from the upper structural components to the foundation [2]. Therefore, the design and analysis of beam and column cross-sections must be carried out systematically using appropriate analytical and computational methods to satisfy the required structural performance criteria [3].



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The two most important geometric parameters in the analysis of concrete beam and column cross-sections are: (1) the centroid and (2) the second moment of area, commonly referred to as the area moment of inertia [4]. The centroid identifies the geometric center of a cross-section and is required to determine the location of the neutral axis and the distribution of internal stresses. Meanwhile, the second moment of area represents the ability of a cross-section to resist bending deformation and deflection under loading [5]. The accuracy of these two parameters significantly affects the results of structural analysis because calculation errors may influence the determination of member dimensions, stiffness, strength, and overall structural stability [6].

In general, the centroid and second moment of area can be determined using two approaches: manual calculations based on engineering mechanics equations and computer-aided analysis using software such as AutoCAD. The manual method provides a systematic understanding of the calculation process because the cross-section is divided into simpler geometric components and each step can be verified individually. However, this method requires a high level of precision and is vulnerable to human error, particularly in determining dimensions, calculating component areas, assigning positive and negative signs, locating local centroids, and applying the parallel-axis theorem to composite or irregular cross-sections [7].

In contrast, AutoCAD enables cross-sectional geometry to be drawn and analyzed more quickly and efficiently, especially for complex shapes. Nevertheless, differences between manual and AutoCAD results may arise from several factors. These include inconsistent reference origins (0,0), differences between local manual coordinates and the active World Coordinate System or User Coordinate System (WCS/UCS), inaccurate drawing dimensions, incorrect scale or unit settings, unclosed polylines, overlapping geometric objects, and rounding during manual calculations. Differences may also occur when the manual analysis simplifies the cross-sectional shape, while AutoCAD calculates the exact geometry represented in the drawing.

Therefore, large differences in centroid coordinates, particularly in support regions, should not immediately be interpreted as software algorithm errors. They may instead result from mismatched coordinate origins or axis orientations between the manual calculation and the AutoCAD model. Before comparison, both methods must use the same reference point, coordinate direction, unit system, and geometric boundaries. Once these parameters are standardized, the results can be compared more accurately and any remaining differences can be attributed to rounding, geometric simplification, or input errors rather than to the AutoCAD calculation algorithm itself [8].

The analysis of beam and column cross-sections is a key part of the planning and construction of the Barak D Yonif TP 847 Bengkulu building. The center of mass (and the cross-sectional moment of inertia) are key factors in designing structural elements that meet strength, stiffness, and safety requirements. Therefore, a study is needed to compare the results obtained using manual methods and AutoCAD. This study compares the two methods in terms of accuracy, time efficiency, and the suitability of the results when applied to simple building structures.

Table 1. Research Gaps in the Study

No.	Researcher/ Year	Research Focus	Key Findings	Limitations of Previous Research	Research Gap
1	Rizaldi dan Setiyarto (2021)	Development of a Visual Basic software tool for calculating the section properties of bridge girder cross-sections	The software is capable of calculating the moment of inertia, the section modulus, and the modulus of elasticity, with results that match those of manual calculations[9]	The study continues to focus on bridge girder cross-sections and specific parameters, and does not yet emphasize flexibility for various general or complex cross-sectional shapes.	A method or system is needed that can calculate cross-sectional parameters in a more general and flexible manner and that can be applied to various types of geometries
2	Huie et al. (2022)	Explanation of the second moment of area and calculations based on	The moment of inertia is an important parameter for assessing flexural strength	Element- or pixel-based approaches tend to be numerically discrete and do not yet	A simpler, more efficient, and more precise approach is needed to calculate cross-sectional

		element/pixel division in cross-sectional shapes	and can be calculated using a discrete element/pixel-based approach[10]	emphasize the efficiency or accuracy of methods based on direct geometric coordinates	properties without relying too heavily on pixel/mesh discretization.
3	Dumka dan Mishra (2025)	Implementation of the Shoelace Method in Python to Calculate the Area, Center of Area, and Moment of Inertia of a Plane	Coordinate-based methods have been shown to be effective for calculating cross-sectional geometric parameters[11]	The study focuses more on the field/polygon in general and has not yet specifically developed integrated applied software for structural cross-section analysis.	There is a need to develop more practical coordinate-based computational methods for civil engineering and structural cross-section analysis.
4	Baba (2024)	Algorithms for calculating the area, center of gravity, moment of inertia, and product of inertia of a polygonal beam; finite element and MSASect2-based analysis	This demonstrates that the properties of free-form cross-sections can be calculated using either polygonal algorithms or finite element methods/specialized software[12]	Research tends to focus on polygonal cross-sections and specialized software, so it may not necessarily be simple or easily accessible for educational purposes or quick calculations	There is a need for methods or tools that are more accessible and simple, yet still accurate, for calculating the cross-sectional properties of various shapes, including free-form shapes

Source: Research Gaps in Research (2021-2025)

Previous research has generally focused on the development of specific software, pixel-based methods, polygon coordinate algorithms, or free-section analysis. However, there has been little research that directly compares manual calculations with AutoCAD results for concrete beam and column cross-sections from real-world projects, particularly by distinguishing between support regions and mid-span regions and analyzing the effect of differences in origin points and coordinate systems on the results for centroids and moments of inertia.

1.1 State of The Art

Advances in civil engineering have shifted cross-sectional analysis from manual calculations to software-based methods that are faster and more efficient. Manually, the centroid, area, and moment of inertia of concrete beam and column cross-sections are calculated using geometric formulas and engineering mechanics principles[13]. Although accurate, this method requires precision, takes more time, and is prone to errors, especially for complex cross-sections. AutoCAD can calculate geometric properties such as area, centroid, and moment of inertia more quickly and efficiently, reducing the potential for manual errors.

However, AutoCAD results still need to be verified using manual calculations because both methods are based on the same geometric and mechanical principles. Differences may result from rounding, drawing accuracy, scale, data input, and coordinate-system settings. The novelty of this study is the comparison of manual and AutoCAD methods for determining the centroid and moment of inertia of concrete beam and column cross-sections in a real construction project. The study compares support and mid-span regions and examines coordinate-system differences, particularly between the reference origin and WCS/UCS. It also proposes coordinate alignment as a step to improve the accuracy and validity of comparisons between the two methods.

1.2 Literature Review

AutoCAD is an engineering drafting software widely used in civil engineering to create accurate two-dimensional and three-dimensional drawings[14]. In this study, beam and polygon cross-sections are analyzed in AutoCAD to determine their area, centroid, and moment of inertia. [15]. Therefore, AutoCAD can provide efficient and accurate analysis, especially for complex cross-sections. It helps users quickly determine dimensions, divide areas, and calculate cross-sectional properties more

systematically than manual methods[16]. Thus, AutoCAD commands make moment of inertia calculations easier and more reliable.

1.2.1 Polyline

In cross-section analysis, polylines are used to define the boundaries of reinforced concrete beams or columns accurately. Closed polylines allow AutoCAD to calculate properties such as area, centroid, and moment of inertia[17]. Therefore, polylines are one of the fundamentals for drawing cross-sections to be analyzed in AutoCAD.

1.2.2 Point

In AutoCAD, a point is used as a reference coordinate to determine the precise position of objects along the X and Y axes[18]. Points not only facilitate work in these two dimensions but also aid in defining cross-sections, thereby enabling the determination of corner points, midpoints, and reference points within a specific boundary.

1.2.3 Region

In AutoCAD, a region is a closed 2D object created by combining drawing elements such as lines, polylines, arcs, circles, or ellipses into one area[19]. Cross-sectional analysis is facilitated through regions, as AutoCAD uses these objects to determine the geometric properties of a plane—its area, center of mass (centroid), and moment of inertia[20].

1.2.4 Massprop

This is AutoCAD Massprop, or Mass Properties, which displays various geometric properties of objects or planar regions[21]. Massprop is useful for cross-section analysis because it provides data such as area, centroid, moment of inertia, and radius of gyration. Therefore, Massprop helps obtain cross-section properties quickly and accurately[22].

2. Research Method

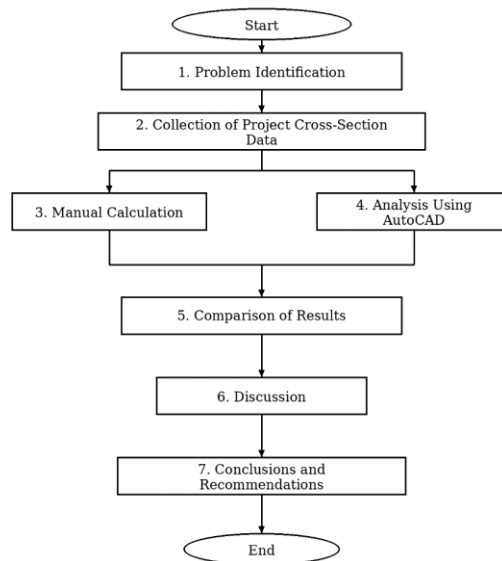


Figure 1. Research Flowchart

This study employs a descriptive-comparative approach by comparing the results of the analysis of the cross-sectional properties of concrete beams and columns using two methods: manual calculations and AutoCAD. The research process began with problem identification, followed by data collection in the form of cross-sectional drawings of concrete beams and columns from the Barak D Yonif TP 847 construction project. The data were then analyzed manually using geometric and engineering mechanics formulas, as well as digitally using AutoCAD. The results from both methods were then compared to determine the level of consistency, accuracy, and any discrepancies that might arise due to technical factors, such as rounding of numbers, drawing accuracy, and data input precision. Subsequently, the research findings were discussed to assess the strengths and weaknesses of each method, concluding with recommendations regarding the reliability and efficiency of using AutoCAD in the analysis of concrete cross-sectional properties.

3. Results and Discussion

3.1 Technical Data

TYPE BALOK	B1		B2	
POSISI	TUMPUAN	LAPANGAN	TUMPUAN	LAPANGAN
POTONGAN				
DIMENSI	200 x 400	200 x 400	150x 300	150x 300
TULANGAN ATAS	2S13	2S13	2S10	2S10
TULANGAN TENGAH	-	-	-	-
TULANGAN BAWAH	2S13	2S13	2S10	2S10
SENGKANG	P8 - 175	P8 - 175	P8 - 150	P8 - 150

Source: Project Data

Figure 2. Project Data in the Beam Reinforcement Working Drawing

TIPE KOLOM	K1	KP
POTONGAN		
DIMENSI	250 x 250	120 x 120
TULANGAN UTAMA	8 S10 (BJTS 420B)	4 P8 (BJTP 280)
SENGKANG TUMPUAN	P8 -175 (BJTP 280)	P8 -200 (BJTP 280)
SENGKANG LAPANGAN	P8 -175 (BJTP 280)	P8 -200 (BJTP 280)

Source: Project Data

Figure 3. Project Data on the Column Reinforcement Working Drawing

3.2 Manual Calculation Results

➤ Calculations in the study for the support section

- Data obtained:
Dimension B1: 400 mm x 200 mm
Dimension K1: 250 mm x 250 mm
- Calculating the areas of Surface I and Surface II on the support object
Formula Equations: $A = P \times L$
Plane I = $P \times L$

$$= 400 \text{ mm} \times 250 \text{ mm}$$

$$= 100.000 \text{ mm}^2$$

 Area II = $P \times L$

$$= 400 \text{ mm} \times 450 \text{ mm}$$

$$= 180.000 \text{ mm}^2$$
- Finding the Center of an Object on the X and Y Axes Using the formula: $(H \frac{1}{2})$
 Plane I

$$X = 250 \text{ mm} \times 0.5$$

$$= 125 \text{ mm}$$

$$Y = 400 \text{ mm} \times 0.5$$

$$= 200 \text{ mm}$$
 Area II

$$X = 450 \text{ mm} \times 0.5$$

$$= 225 \text{ mm}$$

$$Y = 400 \text{ mm} + (400 \times 0.5)$$

$$= 600 \text{ mm}$$
- Finding the moment of inertia of a cross-section Using the formula: $I_g = \frac{bh^3}{12}$
 Area I
$$I_x = \frac{1}{12} \times B \times H^3$$

$$\begin{aligned}
 &= \frac{1}{12} \times 250 \times 400^3 \\
 &= 1.333.333.333,33 \\
 \text{Plane II} \quad I_x &= \frac{1}{12} \times B \times H^3 \\
 &= \frac{1}{12} \times 450 \times 400^3 \\
 &= 2.400.000.000,00
 \end{aligned}$$

- Finding the center of mass in a cross-section along the X and Y axes Using the formula:

$$x = \frac{X_1 \cdot A_1 + X_2 \cdot A_2}{A_1 + A_2} \quad y = \frac{Y_1 \cdot A_1 + Y_2 \cdot A_2}{A_1 + A_2}$$

$$\begin{aligned}
 \text{X-axis} &= \frac{X_1 \cdot A_1 + X_2 \cdot A_2}{A_1 + A_2} \\
 &= \frac{125 \cdot 100.000 + 225 \cdot 180.000}{100.000 + 180.000} \\
 &= 189,29 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Y-axis} &= \frac{Y_1 \cdot A_1 + Y_2 \cdot A_2}{A_1 + A_2} \\
 &= \frac{200 \cdot 100.000 + 600 \cdot 180.000}{100.000 + 180.000} \\
 &= 457,14 \text{ mm}
 \end{aligned}$$

- Find the cross-sectional moment of inertia using the cross-sectional areas at the center of rotation and the center of mass. Using the formula: $I = I_x + A y^2$

$$\begin{aligned}
 I_I &= 1.333.333.333,33 + 100.000 (200 - 457,14)^2 \\
 &= 7.945.578.231,29 \text{ mm}^4
 \end{aligned}$$

$$\begin{aligned}
 I_{II} &= 2.400.000.000,00 + 180.000 (600 - 457,14)^2 \\
 &= 6.073.469.387,76 \text{ mm}^4
 \end{aligned}$$

$$\begin{aligned}
 \text{Total} &= I_I + I_{II} \\
 &= 7.945.578.231,29 \text{ mm}^4 + 6.073.469.387,76 \text{ mm}^4 \\
 &= 14.019.047.619,05 \text{ mm}^4
 \end{aligned}$$

➤ Calculations in the study for the support section

- Data obtained:

Dimension B2: 400 mm x 200 mm

Dimension KP: 250 mm x 250 mm

- Calculating the areas of Surface I and Surface II on the support object

Formula Equations: $A = P \times L$

$$\begin{aligned}
 \text{Plane I} &= P \times L \\
 &= 300 \text{ mm} \times 150 \text{ mm} \\
 &= 45.000 \text{ mm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area II} &= P \times L \\
 &= 300 \text{ mm} \times 300 \text{ mm} \\
 &= 90.000 \text{ mm}^2
 \end{aligned}$$

- Finding the Center of an Object on the X and Y Axes Using the formula: $(H \frac{1}{2})$

$$\begin{aligned}
 \text{Plane I} \\
 X &= 150 \text{ mm} \times 0.5 \\
 &= 75 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 Y &= 300 \text{ mm} \times 0.5 \\
 &= 150 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area II} \\
 X &= 300 \text{ mm} \times 0.5 \\
 &= 150 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 Y &= 300 \text{ mm} + (300 \times 0.5) \\
 &= 450 \text{ mm}
 \end{aligned}$$

- Finding the moment of inertia of a cross-section Using the formula: $I_g = \frac{bh^3}{12}$

$$\text{Area I} \quad I_x = \frac{1}{12} \times B \times H^3$$

$$\begin{aligned}
 &= \frac{1}{12} \times 150 \times 300^3 \\
 &= 375.500.000,00 \\
 \text{Plane II} \quad I_x &= \frac{1}{12} \times B \times H^3 \\
 &= \frac{1}{12} \times 300 \times 300^3 \\
 &= 675.000.000,00
 \end{aligned}$$

- Finding the center of mass in a cross-section along the X and Y axes Using the formula:

$$x = \frac{X_1 \cdot A_1 + X_2 \cdot A_2}{A_1 + A_2} \quad y = \frac{Y_1 \cdot A_1 + Y_2 \cdot A_2}{A_1 + A_2}$$

$$\begin{aligned}
 \text{X-axis} &= \frac{X_1 \cdot A_1 + X_2 \cdot A_2}{A_1 + A_2} \\
 &= \frac{75 \cdot 45.000 + 150 \cdot 90.000}{45.000 + 90.000} \\
 &= 125,00 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Y-axis} &= \frac{Y_1 \cdot A_1 + Y_2 \cdot A_2}{A_1 + A_2} \\
 &= \frac{150 \cdot 45.000 + 450 \cdot 90.000}{45.000 + 90.000} \\
 &= 350,00 \text{ mm}
 \end{aligned}$$

- Find the cross-sectional moment of inertia using the cross-sectional areas at the center of rotation and the center of mass. Using the formula: $I = I_x + A y^2$

$$\begin{aligned}
 I_I &= 375.500.000,00 + 45.000 (150 - 350,00)^2 \\
 &= 2.137.500.000,00 \text{ mm}^4
 \end{aligned}$$

$$\begin{aligned}
 I_{II} &= 675.000.000,00 + 90.000 (450 - 350,00)^2 \\
 &= 1.575.000.000,00 \text{ mm}^4
 \end{aligned}$$

$$\begin{aligned}
 \text{Total} &= I_I + I_{II} \\
 &= 2.137.500.000,00 \text{ mm}^4 + 1.575.000.000,00 \text{ mm}^4 \\
 &= 3.712.500.000,00 \text{ mm}^4
 \end{aligned}$$

➤ Calculations in the field study

- Data obtained:

Dimensions of B1: 400 mm x 200 mm

P = 7000 mm

- Find the area of Surface I on the field object

Formula: $A = P \times L$

$$\begin{aligned}
 \text{Plane I} &= P \times L \\
 &= 400 \text{ mm} \times 7.000 \text{ mm} \\
 &= 2.800.000 \text{ mm}^2
 \end{aligned}$$

- Finding the Center of an Object on the X and Y Axes Using the formula: $(H \frac{1}{2})$

$$\begin{aligned}
 \text{Plane I} \\
 X &= 7.000 \text{ mm} \times 0.5 \\
 &= 3500 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 Y &= 400 \text{ mm} \times 0.5 \\
 &= 200 \text{ mm}
 \end{aligned}$$

- Finding the moment of inertia of a cross-section Using the formula: $I_g = \frac{bh^3}{12}$

$$\begin{aligned}
 \text{Plane I} \quad I_x &= \frac{1}{12} \times B \times H^3 \\
 &= \frac{1}{12} \times 7000 \times 400^3 \\
 &= 37.333.333.318,4
 \end{aligned}$$

- Finding the center of mass in a cross-section along the X and Y axes Using the formula: $X = \frac{X_1 \cdot A_1}{A_1} \quad y = \frac{Y_1 \cdot A_1}{A_1}$

$$\begin{aligned}
 \text{X-axis} &= \frac{X_1 \cdot A_1}{A_1} \\
 &= \frac{3500 \cdot 2.800.000}{2.800.000}
 \end{aligned}$$

$$\begin{aligned}
 &= 3.500 \text{ mm} \\
 \text{Y-axis} &= \frac{Y_1 * A_1}{A_1} \\
 &= \frac{200 * 2.800.000}{2.800.000} \\
 &= 200 \text{ mm}
 \end{aligned}$$

➤ Calculations in the field study

- Data obtained:
Dimensions of B2: 300 mm x 150 mm
P = 7000 mm
- Find the area of Surface I on the field object
Formula: $A = P \times L$
Plane I $= P \times L$
 $= 300 \text{ mm} \times 7,000 \text{ mm}$
 $= 2.100.000 \text{ mm}^2$
- Finding the Center of an Object on the X and Y Axes Using the formula: $(H \frac{1}{2})$
Plane I
X $= 7,000 \text{ mm} \times 0.5$
 $= 3500 \text{ mm}$
Y $= 300 \text{ mm} \times 0.5$
 $= 150 \text{ mm}$
- Finding the moment of inertia of a cross-section Using the formula: $I_g = \frac{bh^3}{12}$
Plane I $I_x = \frac{1}{12} \times B \times H^3$
 $= \frac{1}{12} \times 7000 \times 300^3$
 $= 15.749.999.993,7$
- Finding the center of mass in a cross-section along the X and Y axes Using the formula: $X = \frac{X_1 * A_1}{A_1}$ $y = \frac{Y_1 * A_1}{A_1}$
X-axis $= \frac{X_1 * A_1}{A_1}$
 $= \frac{3500 * 2.800.000}{2.800.000}$
 $= 3.500 \text{ mm}$
Y-axis $= \frac{Y_1 * A_1}{A_1}$
 $= \frac{150 * 2.100.000}{2.100.000}$
 $= 150 \text{ mm}$

➤ Calculations in the field study

- Data obtained:
Dimensions of K1: 250 mm x 250 mm
T = 4000 mm
- Find the area of Surface I on the field object
Formula: $A = P \times L$
Plane I $= P \times L$
 $= 250 \text{ mm} \times 4000 \text{ mm}$
 $= 1.000.000 \text{ mm}^2$
- Finding the Center of an Object on the X and Y Axes Using the formula: $(H \frac{1}{2})$
Plane I
X $= 250 \text{ mm} \times 0.5$
 $= 125 \text{ mm}$
Y $= 4000 \text{ mm} \times 0.5$
 $= 2000 \text{ mm}$
- Finding the moment of inertia of a cross-section Using the formula: $I_g = \frac{bh^3}{12}$

$$\begin{aligned}
 \text{Plane I } I_x &= \frac{1}{12} x B x H^3 \\
 &= \frac{1}{12} x 250 x 4000^3 \\
 &= 1.333.333.332.800
 \end{aligned}$$

- Finding the center of mass in a cross-section along the X and Y axes Using the formula: $X = \frac{X_1 * A_1}{A_1}$ $y = \frac{Y_1 * A_1}{A_1}$

$$\begin{aligned}
 \text{X-axis} &= \frac{X_1 * A_1}{A_1} \\
 &= \frac{125 * 1.000.000}{1.000.000} \\
 &= 125 \text{ mm} \\
 \text{Y-axis} &= \frac{Y_1 * A_1}{A_1} \\
 &= \frac{2000 * 1.000.000}{1.000.000} \\
 &= 2000 \text{ mm}
 \end{aligned}$$

3.3 Results of the Analysis Using AutoCAD

- Calculations in the study regarding the support section

- Data obtained:
Dimensions of B1: 400 mm x 200 mm
Dimensions of K1: 250 mm x 250 mm
Creating Dimensions Using the Polyline Command

```

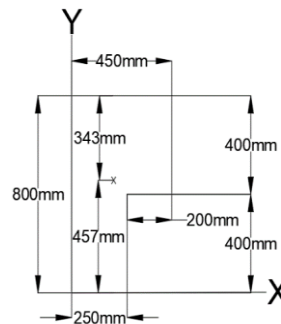
Command: POLYLINE
PLINE
Specify start point:
Current line-width is 0.00
Specify next point or [Arc/Halfwidth/Length/Undo/Width]: 250
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 400
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 200
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 400
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 450
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 800
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]:

```

Source: Author

Figure 9. Results of the Polyline Command for Objects B1 and K1

- Finding the center of gravity in a cross-section of the support area
Determining the center of gravity value using the PO (Point) command



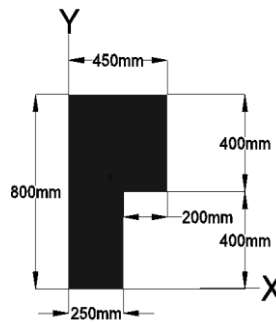
Source: Author

Figure 12. Results of Determining the Distance of the Center of Gravity from the PO (Point) Command for Object B1 and K1

The results show the center of mass values from the PO (Point) command. The distance between the X and Y axes

X: 457 mm
Y: 343 mm

- Calculating the moment of inertia using the Region+Masproop command Activating the Region command on an object



Source: Author

Figure 13. Object Results for the Region Command with Dimensions B1 and K1

Result of the moment of inertia value in the Masproop command

```
Principal moments and X-Y directions about centroid:
I: 14651763624.58 along [0.97 -0.24]
J: 3568474470.66 along [0.24 0.97]
```

Source: Author

Figure 14. Results of the Moment of Inertia Values for the Massprop Command with Dimensions B1 and K1

Results of the moment of inertia values in the Support area in the Masproop command

$$I = 14,651,763,624.58 \text{ mm}^4$$

➤ Calculations in the study for the support section

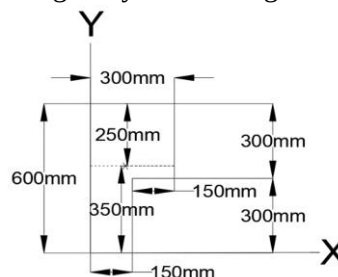
- Data obtained:
Dimensions of B2: 300 mm x 150 mm
Dimensions of KP: 120 mm x 120 mm
Creating Dimensions in the Polyline command

```
Command: POLYLINE
PLINE
Specify start point:
Current line-width is 0.00
Specify next point or [Arc/Halfwidth/Length/Undo/Width]: 150
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 300
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 150
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 300
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 300
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 600
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]:
```

Source: Author

Figure 15. Results of the Polyline Command Applied to Objects B2 and KP

- Finding the center of gravity in a cross-section of the B2 and KP support areas
Determining the center of gravity value using the PO (Point) command



Source: Author

Figure 18. Results of the Object Determining the Distance to the Center of Gravity Using the PO (Point) B2 and KP

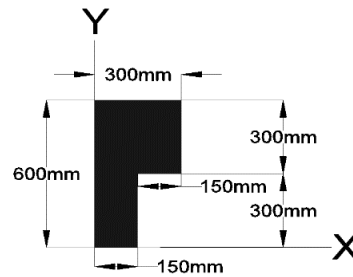
The results show the center of mass values from the PO (Point) command. The distance between the X and Y axes

X: 350 mm

Y: 250 mm

- Find the moment of inertia using the Region+Masproop command

Activating the Region command on an object



Source: Author

Figure 19. Object Results for the Region Command in Dimensions B2 and KP

Moments of inertia results in the Massprop command

```
Principal moments and X-Y directions about centroid:  
I: 3867507069.26 along [0.97 -0.22]  
J: 773117930.74 along [0.22 0.97]
```

Source: Author

Figure 20. Results of the Moment of Inertia Values for the Massprop Command in Dimensions B2 and KP

Results of the moment of inertia values in the Support area in the Massprop command

$$I = 3,867,507,069.26 \text{ mm}^4$$

➤ Calculations in the study for the Field section

- Data obtained:

Dimensions of B1: 400 mm x 200 mm

P = 7,000 mm

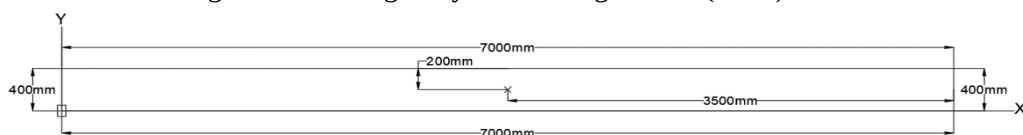
Create dimensions using the Polyline command

```
Command: POLYLINE  
PLINE  
Specify start point:  
Current line-width is 0.00  
Specify next point or [Arc/Halfwidth/Length/Undo/Width]: 400  
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 7000  
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 400  
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 7000  
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]:
```

Source: Author

Figure 21. Result of the Polyline B1 Command

- Finding the center of gravity in a cross-section of the Field
Determining the center of gravity value using the PO (Point) command



Source: Author

Figure 24. Results of Determining the Distance to the Center of Gravity Using the PO (Point) Command on Object B1

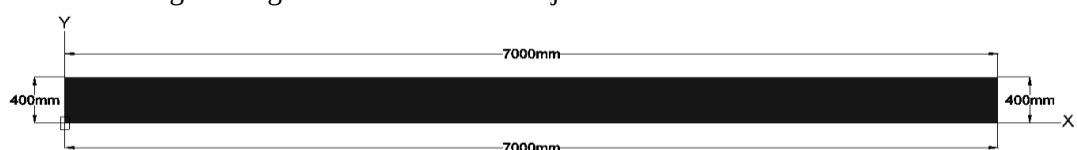
The results show the center of mass value from the PO (Point) command. The distance between the X and Y axes

X: 3,500 mm

Y: 200 mm

Calculating the moment of inertia using the Region+Massprop command

Activating the Region command on an object



Source: Author

Figure 25. Object Results from the Region Command on Dimension B1

Result of the moment of inertia value in the Masproop command

```
Principal moments and X-Y directions about centroid:
I: 37333333333.36 along [1.00 0.00]
J: 1.14E+15 along [0.00 1.00]
```

Source: Author

Figure 26. Results of the Moment of Inertia Values for the Masproop Command in Dimension B1

The results of the moment of inertia values for the field area in the Massprop command are shown

$$I = 37,333,333,333.36 \text{ mm}^4$$

➤ Calculations in the study for the Field section

- Data obtained:

Dimensions of B2: 300 mm x 150 mm

P = 7,000 mm

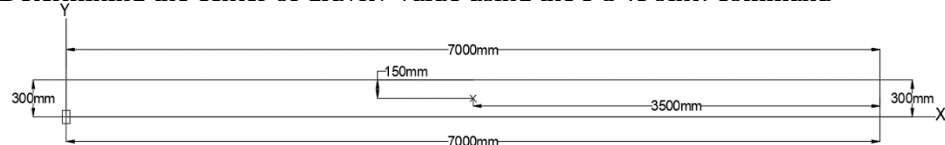
Create dimensions using the Polyline command

```
Command: POLYLINE
PLINE
Specify start point:
Current line-width is 0.00
Specify next point or [Arc/Halfwidth/Length/Undo/Width]: 300
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 7000
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 300
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 7000
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]:
```

Source: Author

Figure 27. Command Object Results from the B2 Polyline Command

- Finding the center of gravity in a cross-section of the Field
Determining the center of gravity value using the PO (Point) command



Source: Author

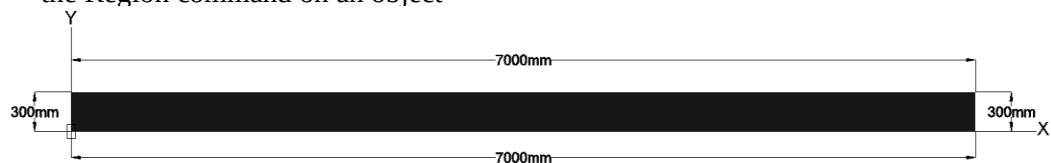
Figure 30. Results of Determining the Distance to the Center of Gravity Using the PO (Point) B2 Command

The result shows the center of mass value from the PO (Point) command. The distance between the X and Y axes

X: 3,500 mm

Y: 150 mm

- Calculating the moment of inertia using the Region+Masproop command Activating the Region command on an object



Source: Author

Figure 31. Object Results for the Region Command on Dimension B2

Result of the moment of inertia value in the Masproop command

```
Principal moments and X-Y directions about centroid:
I: 15749999999.97 along [1.00 0.00]
J: 85749999999.99 along [0.00 1.00]
```

Source: Author

Figure 32. Results of the Moment of Inertia Values for the Massprop Command in Dimension B2

Results of the moment of inertia values for the Field area in the Massprop command

$$I = 15,749,999,999.97 \text{ mm}^4$$

➤ Calculations in the study for the Field section

- Data obtained:

Dimensions of K1 = 250 mm x 250 mm

T = 4,000 mm

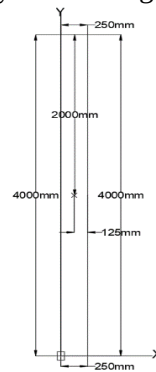
Create dimensions using the Polyline command

```
Command: POLYLINE
PLINE
Specify start point:
Current line-width is 0.00
Specify next point or [Arc/Halfwidth/Length/Undo/Width]: 250
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 4000
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 250
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]: 4000
Specify next point or [Arc/Close/Halfwidth/Length/Undo/Width]:
```

Source: Author

Figure 33. Result of the Polyline K1 Command

- Finding the center of gravity in a cross-section of the K1 Field
Determining the center of gravity value using the PO (Point) command



Source: Author

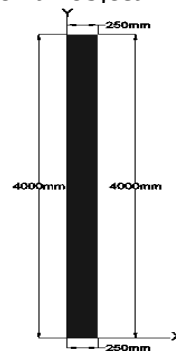
Figure 36. Results of Determining the Distance to the Center of Gravity Using the PO (Point) Command on Object K1

The results show the coordinates of the center of mass from the PO (Point) command. The distance between the X and Y axes

X: 125 mm

Y: 2000 mm

- Find the moment of inertia using the Region+Masproop command
Activating the Region command on an object



Source: Author

Figure 37. Object Results for the Region Command on Dimension K1
Result of the moment of inertia value in the Masproop command

```
Principal moments and X-Y directions about centroid:
I: 1333333333333.31 along [1.00 0.00]
J: 5208333333.32 along [0.00 1.00]
```

Source: Author

Figure 38. Results of the Moment of Inertia Values for the Massprop Command in Dimension K1

Results of the moment of inertia values for the field area in the Massprop command

$I = 1,333,333,333,333.31 \text{ mm}^4$

3.4 Comparison of Manual and AutoCAD Results

Table 2. Results of Center of Gravity and Moment of Inertia Calculations

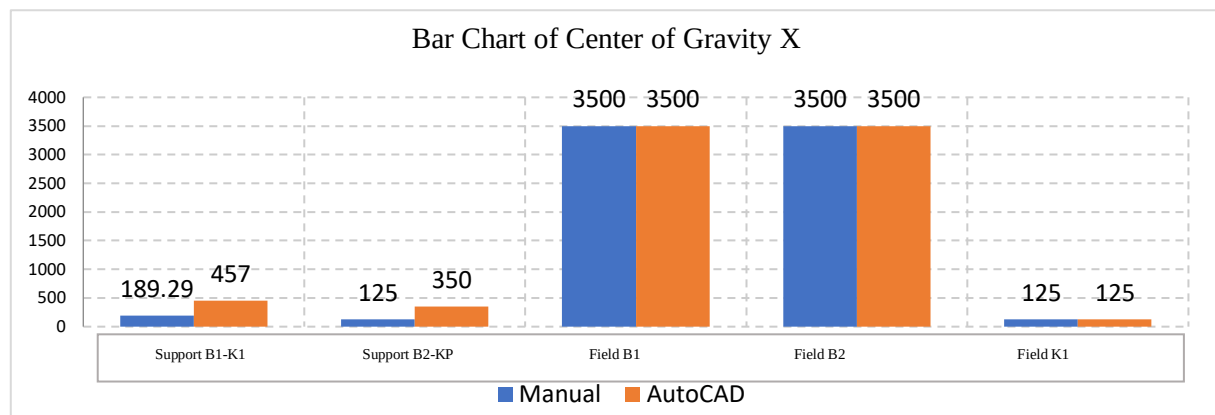
No	Part/Object	Method	Center of Gravity X (mm)	Center of Gravity Y (mm)	Moment of Inertia, I (mm ⁴)
1	Support B1–K1	Manual	189,29	457,14	14.019.047.619,05
2	Support B1–K1	AutoCAD	457	343	14.651.763.624,58
3	Support B2–KP	Manual	125,00	350,00	3.712.500.000,00
4	Support B2–KP	AutoCAD	350	250	3.867.507.069,26
5	Field B1	Manual	3.500	200	37.333.333.318,4
6	Field B1	AutoCAD	3500	200	37.333.333.333,36
7	Field B2	Manual	3.500	150	15.749.999.993,7
8	Field B2	AutoCAD	3.500	150	15.749.999.999,97
9	Feild K1	Manual	125	2000	1.333.333.332.800
10	Lapangan K1	AutoCAD	125	2.000	1.333.333.333.333,31

Source: Research Results

Table 3. Differences Between Manual and AutoCAD Calculation Results

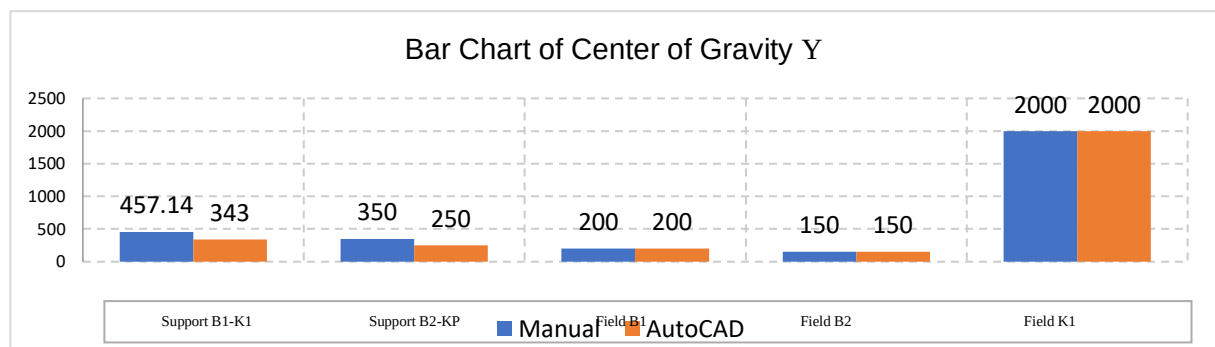
No	Part/ Object	Difference in Center of Gravity X (mm)	Percentage Difference X (%)	Difference in Center of Gravity Y (mm)	Percentage Difference Y (%)	Differen ce in Moment of Inertia I (mm ⁴)	Percentage Difference in I (%)
1	Support B1–K1	267,71	58,58	114,14	33,28	632.716.005,53	4,31836072
2	Support B2–KP	225,00	64,29	100,00	40,00	155.007.069,26	4,00793241
3	Field B1	0,00	0,00	0,00	0,00	14,96	0,00000004
4	Field B2	0,00	0,00	0,00	0,00	6,27	0,00000004
5	Field K1	0,00	0,00	0,00	0,00	533,31	0,00000004

Source: Research Data



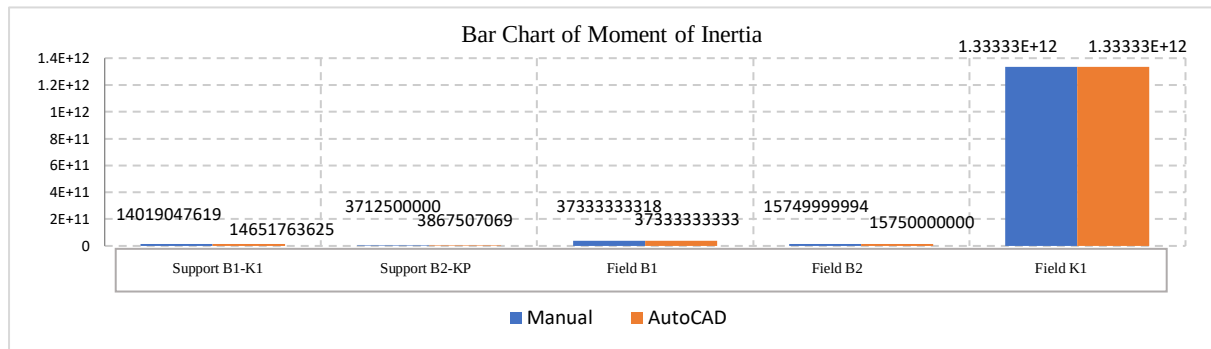
Source: Research Data

Figure 39. Bar Chart of Center of Gravity on the X-Axis



Source: Research Data

Figure 40. Bar Chart of the Center of Gravity on the Y-Axis



Source: Research Data

Figure 41. Bar Graph of Bar vs. Moment of Inertia in Manual and AutoCAD Calculations

4. Conclusion

The comparison results show that the best agreement between the manual calculations and the AutoCAD analysis was obtained in the central sections of spans B1, B2, and K1, with a coordinate variance of 0.00%. These results indicate that both methods yield consistent centroid values, while the differences in the values of the moment of inertia are relatively very small. In contrast, in the B1–K1 and B2–KP support sections, significant coordinate differences were found, exceeding 58%. These differences were not caused by inaccuracies in the AutoCAD algorithm but rather by discrepancies in the reference origin (0,0) and axis orientation between the manual calculations and the WCS/UCS coordinate systems in AutoCAD. Therefore, the coordinate systems for the support sections must first be aligned before the results of the two methods can be directly compared. Overall, both manual and AutoCAD calculations yielded more stable and consistent results for the central span section compared to the support sections.

Overall, the advantage of manual calculation methods based on fundamental engineering mechanics formulas lies in their thoroughly documented process. Each step of the calculation is traceable, so this method demonstrates a strong understanding of the fundamental concepts of engineering mechanics. However, the manual method takes longer and carries a risk of human error, particularly in determining dimensions, calculating areas, determining the centroid, and performing other arithmetic operations. In contrast, AutoCAD can produce analyses more quickly and efficiently, especially for cross-sections with complex geometric shapes. Nevertheless, the accuracy of AutoCAD results heavily depends on the accuracy of input data, such as scale, boundary dimensions, cross-section shape, and the coordinate system used [23]. Furthermore, AutoCAD analyzes only the geometric properties of the cross-section and does not account for concrete material characteristics, reinforcement configuration, the type and timing of prestressing, cracking conditions, or actual field conditions [24]. Therefore, AutoCAD can be used as a tool for preliminary analysis, but the results must be cross-verified with manual calculations and well-established principles of engineering mechanics to ensure that the analysis results are more accurate, theoretically valid, and technically sound [25].

5. Acknowledgments

The author would like to thank Allah SWT for His grace, which enabled the completion of this research. Appreciation is also extended to Al-Azhar University Medan, the academic advisor, all faculty members, family, and everyone who provided support in the preparation of this research.

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