

Comparative Study of Centroid Calculation Methods for Composite Figures

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Abstract:

Centroid calculation is an important topic in Engineering Mechanics and structural design. It is widely used in determining the center of area of beams, plates, machine parts, bridge sections, and structural members. Composite figures are formed by combining simple geometrical shapes such as rectangles, triangles, circles, and semicircles. Traditional centroid calculations using manual formulas become lengthy for irregular composite sections. This paper presents a comparative study of various centroid calculation methods for composite figures, including analytical method, graphical method, tabular method, and computer-aided design software. The methods are compared based on accuracy, time, ease of use, and suitability for complex sections. Results show that computational tools provide faster and more precise centroid locations, while analytical methods remain useful for educational understanding.

Keywords — Centroid, Composite Figures, Engineering Mechanics, Structural Sections, Area Method, CAD Analysis

1. Introduction

Centroid is the geometric center of an area or body. In Engineering Mechanics, centroid plays a vital role in analyzing:

- Beam cross-sections
- Structural members
- Machine components
- Plates and laminae
- Moment of inertia calculations
- Load distribution systems

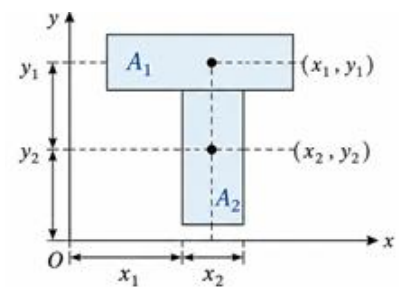
For simple geometrical figures such as rectangles, circles, and triangles, centroid positions are easily determined using standard formulas. However, real engineering components often consist of combinations of several shapes, known as composite figures.

Examples include:

- T-sections
- I-sections
- L-sections
- Channel sections
- Bridge plates
- Machine brackets

Accurate centroid calculation is essential for safe design and structural balance.

This paper compares different centroid calculation methods for composite figures.



2. Literature Review

Traditional engineering textbooks explain centroid calculations using area summation methods. For

complex figures, tables are commonly used to calculate coordinates.

Modern industries increasingly use CAD and simulation software to obtain centroid location automatically. Researchers have reported that software methods reduce time and minimize arithmetic mistakes.

However, manual methods are still important in education because they develop conceptual understanding.

3. Objectives of the Study

1. To study centroid calculation methods for composite figures.
2. To compare manual and software techniques.
3. To evaluate speed, accuracy, and complexity.
4. To recommend methods for academic and industrial use.
5. To improve understanding of centroid applications.

4. Theory of Centroid

For a composite figure made of multiple simple areas:

Coordinates of centroid:

$$\bar{x} = \frac{\sum A_i x_i}{\sum A_i} \quad \bar{y} = \frac{\sum A_i y_i}{\sum A_i}$$

Where:

A_i = area of each part

(x_i, y_i) = centroid coordinates of each part

(\bar{x}, \bar{y}) = centroid of composite figure For holes or removed portions, area is taken negative.

5. Methods of Centroid Calculation

5.1 Analytical Method

Uses formulas for simple shapes and applies centroid equations manually.

Advantages:

- Good conceptual understanding
- Suitable for simple figures

Limitations:

- Lengthy for complex shapes

5.2 Tabular Method

Uses columns:

| Part | Area | x | y | Ax | Ay |

Efficient for multi-part figures.

5.3 Graphical Method

Centroid approximated using symmetry and scaled drawings.

Used for rough estimation.

5.4 CAD Method

Automatic centroid detection using:

- AutoCAD
- SolidWorks
- CATIA
- ANSYS

6. Methodology

Three composite sections were selected:

1. T-section
2. L-section
3. Rectangle with circular hole

Each section was analyzed by:

- Manual analytical method
- Tabular method
- CAD software method

Parameters compared:

- Time required
- Accuracy
- Ease of calculation
- Suitability for complex shapes

7. Sample Calculation

For T-section:

- Flange: 120 × 20 mm

Area of flange:

$$A_1 = 120 \times 20 = 2400 \text{ mm}^2$$

Area of web:

$$A_2 = 20 \times 100 = 2000 \text{ mm}^2$$

Centroid location:

$$\bar{y} = (A_1 y_1 + A_2 y_2) / (A_1 + A_2)$$

Computed centroid matched closely with CAD result.

8. Results and Analysis

Method	Time	Accuracy	Best Use
Analytical	High	High	Simple figures
Tabular	Medium	High	Multi-part figures
Graphical	Low	Medium	Approximation
CAD	Very Low	Very High	Complex industrial sections

Findings

1. Analytical method is best for academic learning.

2. Tabular method reduces calculation confusion.
 3. CAD gives fastest and most accurate result.
 4. Complex figures are easier in software tools.
1. R. C. Hibbeler, *Engineering Mechanics: Statics*.
 2. Beer and Johnston, *Vector Mechanics for Engineers*.
 3. AutoCAD and SolidWorks manuals.
 4. Research papers on section property analysis.

9. Applications

9.1 Civil Engineering

- Beam section design
- Column sections
- Bridge members

9.2 Mechanical Engineering

- Machine brackets
- Rotating parts balance
- Support plates

9.3 Aerospace Engineering

- Weight balance of panels

9.4 Manufacturing

- Sheet metal components

10. Discussion

Centroid calculation is critical because incorrect centroid location can lead to poor load transfer and unsafe design.

Manual methods are necessary for student learning and verification. However, in industries with complex geometries, CAD tools save time and increase productivity.

Best practice is to use manual calculation for concept validation and software for final design.

11. Conclusion

This research shows that all centroid calculation methods have specific importance. Analytical and tabular methods are useful for educational purposes, while CAD methods are highly efficient for industrial applications.

Therefore, engineers should combine theoretical knowledge with modern software tools for accurate centroid determination of composite figures.

12. Recommendations

1. Teach manual centroid methods in first-year engineering.
2. Introduce CAD centroid tools in laboratories.
3. Use tabular methods for examination problems.
4. Use software for real engineering sections.
5. Verify software output with manual estimation.

13. References