STAMS 2025
SEMTA-AIMETA COLLOQUIUM
Mechanics Across Realms: Experiments to Theory (and back)
23-25 APRIL 2025, GRANADA, SPAIN

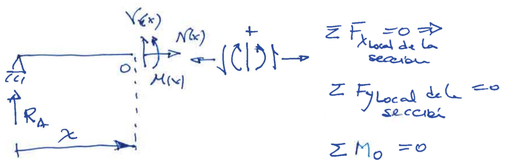
Algebraic and Analytical Approaches to the Calculation of Internal Forces and the Internalization of Structural Equilibrium: A Teaching Experience in Engineering

Granados, J.J.; Comino, L.; Bravo, R; and Palma, R.
Department of Structural Mechanics, University of Granada -18071 Granada, Spain

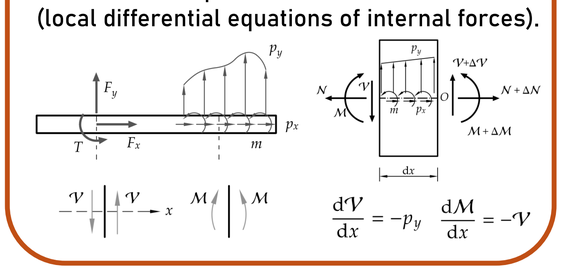
1. INTRODUCTION

Structural equilibrium is a fundamental concept in structural mechanics and essential in engineering education. Among the approaches for calculating internal forces, two are particularly relevant:

ALGEBRAIC METHOD (AG)
Based on the equilibrium of an isolated part of the structure (global equilibrium approach).



ANALYTICAL METHOD (AN)
Based on the equilibrium of a differential slice (local differential equations of internal forces).



This Teaching Innovation Project at the University of Granada aims to identify which approach better fosters understanding, critical thinking, and academic performance across engineering degrees. The initiative aligns with the principles of the European Higher Education Area (EHEA) and its emphasis on student-centered learning (ESG 2015), incorporating active methodologies, digital materials, and attention to student diversity. In doing so, it promotes a more inclusive, sustainable, and effective teaching practice.

2. MOTIVATION, RESEARCH QUESTIONS AND OBJECTIVES

There is a lack of empirical evidence on the effectiveness of current teaching approaches in structural analysis. This project addresses that gap by comparing methods to improve student understanding. Given the high mathematical and physical abstraction of the subject, students from different engineering degrees show distinct preferences for analytical or physical-graphical reasoning. Traditional lectures have led to disengagement. This project seeks to adapt teaching strategies to enhance student motivation, comprehension, and performance in a cognitively demanding field.

RESEARCH QUESTIONS

1. Does method choice influence students' conceptual internalization of equilibrium?
2. Which approach yields higher accuracy in solving unseen problems?
3. How do students perceive difficulty, confidence and motivation before and after instruction?

OBJECTIVES

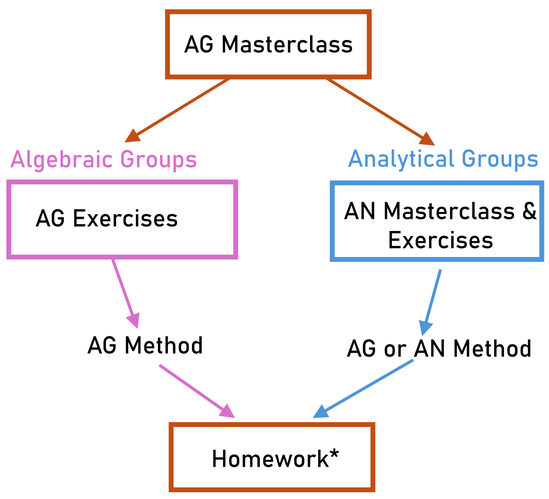
- Compare teaching approaches (algebraic vs analytical) to determine which is more effective, aiming to improve learning outcomes and the acquisition of core competencies in structural equilibrium and internal force analysis.
- Promote student-centered strategies that address diverse cognitive profiles—mathematical and physical-graphical—enhancing both conceptual understanding and engagement with structural behavior.
- Foster critical thinking and autonomy by reinforcing abstract reasoning skills, practical intuition, and problem-solving abilities relevant to real-world engineering contexts.

3. METHODOLOGY

The project adopts a student-centered approach to reinforce both AG and AN methods for internal force analysis in the Electronic Engineering Degree. Flexible learning pathways and diversified materials are offered to accommodate the varying backgrounds and needs of students from different engineering degrees.

Key strategies include:
- Active learning tasks tailored to specific skills and course objectives.
- Use of self-assessment tools to promote autonomous learning.
- Group tutorials to provide guidance and foster collaboration.
- Adaptive reinforcement exercises focused on the less familiar method in each degree program.

Students complete tailored questionnaires throughout the course to assess their experience, learning difficulties, and the effectiveness of the methods. These results, along with academic performance, will be analyzed to evaluate the project's impact.



(*) Homework was completed by teams of 3 to 5 students

HOMEWORK

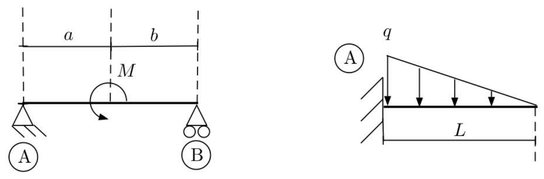
RESISTENCIA DE MATERIALES
Curso 2024/25
Actividad de la sesión práctica 1: Leyes de esfuerzos

APELLIDOS:

NOMBRE: **DNI/NIE:**

Actividad 1

Considere las siguientes vigas donde los parámetros se refieren a los dígitos no nulos del DNI/NIE. Por ejemplo, A3201... $X_1 = 3$, $X_2 = 2$, $X_3 = 1$ ...



4. RESULTS & DISCUSSION

INSTRUMENTS & DATA

Instrument	Purpose	Sample Items / Metrics
Diagnostic survey	Prior knowledge & expectations	Predicted score (0–10); Anticipated difficulty level
Post survey	Conceptual gains & motivation	Correct locn of max shear/moment; preferred method
Rubric grading	Performance evidence	Mean rubric score per problem (0–5)
Tutor notes	Qualitative insights	Misconceptions observed

- Accuracy: Algebraic groups scored 3.9 ± 0.6 on shear vs 3.4 ± 0.7 for Analytical; conversely, Analytical groups excelled in bending moment for the triangular load (3.8 ± 0.5 vs 3.1 ± 0.8). Scores are assessed using a maximum of 5 according to the rubric.
- Conceptual links: 72 % of Analytical teams recognised the derivative relation V(x)=dM(x)/dx in the post survey vs 41 % of Algebraic.
- Method choice at home: All teams solved the point moment load beam algebraically; 50 % of Analytical teams switched to AN method for the triangular beam, attaining the top three rubric scores.
- Perceived difficulty: Median self-reported difficulty dropped from "high" to "medium" only in the Analytical groups.

The algebraic approach better supports quick-reaction equilibrium tasks, while the analytical route deepens understanding of load intensity relationships and scaling to complex distributions. A blended sequence—algebraic first, analytical second—may therefore maximise learning within limited contact hours.

5. CONCLUSIONS & ACKNOWLEDGMENTS

CONCLUSIONS

- The algebraic method (AG) is more intuitive for students with limited mathematical background, leading to better performance in problems involving concentrated loads.
- The analytical method (AN) is more effective for solving problems with complex distributed loads, with students achieving higher scores when using it appropriately.
- Allowing students to choose their preferred method fosters autonomy, motivation, and deeper understanding of internal structural forces.
- Future work: to deepen and extend the study to other engineering degree programs at UGR.

ACKNOWLEDGEMENTS

Innovation Project PID UGR 2024-76 "Cálculo de Esfuerzos: Comparación de los Enfoques Analítico y Algebraico" funded by the Quality, Innovation and Foresight Unit, University of Granada. Special thanks to the 2024/25 Strength of Materials students of the Electronic Engineering Degree.

BIBLIOGRAPHY

- López Zafra E. et al. (2015) Rev. Innov. Docent Univ., 7, 71-80.
- Granados J.J. et al. (2024) Problemas resueltos de Resistencia de Materiales y T. de Estructuras
- Moliner E. & Martínez Rodrigo M.D. (2017) INDOTEC V Proceedings.
- Rus G. & Comino L. (2014) Resistencia de Materiales.

UNIVERSIDAD DE GRANADA