The Hong Kong University of Science and Technology

UG Course Syllabus

Structural Analysis

CIVL3310

3 Credits

Name: Shenghan ZHANG

Email: ceshenghan@ust.hk

Office Hours: By email appointments

Course Description

Structural Analysis introduces how structures carry loads, develop internal forces, and deform, providing a foundation for structural design. The course begins with historical context, the design process, structural forms and classification, load types and combinations, and the specification of forces. Students learn equilibrium and statics through free-body diagrams, internal versus external forces, computation of reactions, and compatibility and displacement conditions, leading to notions of stability, determinacy, and indeterminacy.

After introducing the principle of superposition, the course covers plane and space trusses, including modeling assumptions, notation, member arrangements, and analysis by the method of joints, method of sections, and strategies for compound and complex trusses. Beam and frame behavior follows, including axial, shear, and bending actions; sign conventions; qualitative deflected shapes; and the load–shear–moment relationships. Multiple deflection techniques are developed—the differential equation, the conjugate-beam method, energy methods (conservation of energy, virtual work), and Castigliano's theorems—complemented by Betti's and Maxwell's reciprocity and the principle of influence lines for moving-load effects.

The course introduces analysis of statically indeterminate systems via the force method (including redundants in beams, frames, and trusses; support settlement; temperature changes; shrinkage; and fabrication errors) and displacement-based approaches using slope-deflection equations and moment distribution for beams and frames with and without side-sway, including stiffness-factor modifications. Throughout, emphasis is placed on modeling assumptions, verification checks, and connecting analytical results to engineering judgment and preliminary design decisions.

Intended Learning Outcomes (ILOs)

By the end of this course, students should be able to:

- ILO1: Identify structural forms; classify structure types (beams, trusses, frames, cables); characterize load types, combinations, and load paths within a structural system; and assess stability, determinacy, and indeterminacy.
- ILO2: Construct free-body diagrams and apply equilibrium to compute reactions and internal forces, using consistent sign conventions and justifying assumptions.
- ILO3: Analyze plane and space trusses using appropriate strategies for compound/complex trusses; evaluate determinacy and idealization assumptions.
- ILO4: Derive and interpret shear force and bending moment diagrams for beams and frames; relate distributed loads, shear, and moment through differential relationships and boundary conditions. Understand the relationship between loads, shear forces and bending moments.
- ILO6: Determine deflections of trusses, beams, and frames using differential equations, conjugate beam method, virtual work, and Castigliano's theorems.
- ILO7: Explain and apply Betti's and Maxwell's reciprocity and construct and use influence lines for reactions, shear, and moment to evaluate effects of moving loads and critical load positions.
- ILO8: Perform analysis of statically indeterminate structures using the force method, including effects of support settlement, temperature change, shrinkage, and fabrication errors.
- ILO9: Formulate and solve displacement-based analyses using slope-deflection equations and moment distribution for beams and frames, with and without side-sway, including stiffness modifications.

Assessments:

Assessment Task	Contribution to Overall Course grade (%)	Due date
In-class activities	10%	To be announced.
Homework assignments + Laboratory experiments	10%	
Mid-term exam	30%	
Final exam	50%	

Mapping of Course ILOs to Assessment Tasks

Assessed Task	Mapped ILOs	Explanation
In-class activities	ILO1, ILO2, ILO3, ILO4	Guided problem-solving, clicker questions, and short whiteboard exercises on FBDs, reactions, truss joints/sections, and shear–moment relations reinforce fundamentals and provide immediate feedback on misconceptions.
Homework assignments	ILO1, ILO2, ILO3, ILO4, ILO6, ILO7, ILO8, ILO9	Multi-step problems require full analyses across topics: classification and load paths, equilibrium and internal forces, truss/beam/frame analysis, deflections by several methods, influence lines, and indeterminate analyses via force and displacement methods.
Laboratory experiments	ILO2, ILO4, ILO6, ILO7	Hands-on or virtual labs (e.g., strain/deflection measurements, conjugate-beam demonstrations, influence-line experiments) link theory to measured response, emphasizing setup of FBDs, shear/moment interpretation, and validation of deflection/influence-line predictions.
Mid-term exam	ILO1, ILO2, ILO3, ILO4, ILO6	Cumulative assessment of early-to-mid topics: classification and stability, equilibrium and reactions, truss analysis, shear–moment diagrams, qualitative deflected shapes, and introductory deflection methods.
Final exam	ILO1, ILO2, ILO3, ILO4, ILO6, ILO7, ILO8, ILO9	Integrative assessment covering the full course, including influence lines and indeterminate analyses (force method, slope-deflection, moment distribution), with synthesis across multiple concepts and validation checks.

Final Grade Descriptors:

Grades	Short Description	Elaboration on subject grading description

A	Excellent Performance	Demonstrates deep, accurate understanding across all Structural Analysis topics, integrating equilibrium/FBDs, internal forces, trusses, beams/frames, deflection methods, influence lines, and indeterminate analysis (force and displacement methods). Selects and justifies the most suitable analysis method; compares alternatives; clearly states and evaluates modeling assumptions, superposition applicability, and limitations. Produces precise, well-labeled calculations and diagrams (shear/moment, qualitative deflected shapes, influence lines), with consistent sign conventions and rigorous error checks (equilibrium, units, symmetry, limiting cases, reciprocity). Solves unfamiliar, multi-step problems with originality and engineering judgment, including effects of settlement, temperature, shrinkage, and fabrication errors. Communicates clearly and professionally; results are traceable and linked to design implications (member sizing tendencies, serviceability).
B	Good Performance	Shows solid command of core methods and concepts with minor errors or occasional gaps in integration. Generally chooses appropriate methods and states key assumptions; performs sound calculations for reactions, truss forces, V/M diagrams, deflections, and basic indeterminate cases. Applies sign conventions consistently; conducts relevant checks, though depth or completeness may vary. Handles standard and moderately novel problems; connects results to practical interpretation with mostly clear communication.
C	Satisfactory Performance	Demonstrates adequate understanding of major topics (equilibrium, trusses, beams/frames, basic deflection) but with limited integration across concepts. Can complete routine computations for FBDs, reactions, truss joints/sections, and V/M diagrams; deflection and

		indeterminate analyses show partial correctness or rely on guided procedures. Assumptions and sign conventions are stated inconsistently; error checking is minimal; qualitative deflected shapes and influence lines may contain notable mistakes. Communication is understandable but uneven; links to design implications are basic.
D	Marginal Pass	Possesses basic knowledge of terminology and procedures but exhibits frequent errors in equilibrium application, internal force determination, or diagram construction. Method selection is often inappropriate or unjustified, weak grasp of assumptions, compatibility, and superposition. Deflection and indeterminate analyses are largely incorrect or incomplete; limited ability to perform checks or interpret physical plausibility. Communication lacks clarity and organization; results are difficult to trace and rarely connected to design meaning.
F	Fail	Shows insufficient understanding of Structural Analysis fundamentals; misapplies or omits equilibrium and FBDs; internal forces, V/M diagrams, or truss analyses are predominantly incorrect. Unable to select or execute appropriate methods for deflection, influence lines, or indeterminate structures; assumptions and compatibility are ignored. Provides little to no error checking; results are physically inconsistent. Communication is unclear or incomplete, preventing assessment of reasoning or outcomes.

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Mapping to Course ILOs
Integration and Analysis of Structural Concepts	Demonstrates insightful, accurate synthesis across core topics (equilibrium/FBDs, internal forces, trusses/beams/frames, deflections, indeterminacy). Clearly explains how concepts interrelate (e.g., load–shear–moment relations informing design judgments), with nuanced discussion of limitations and assumptions.	Accurately connects multiple course topics and explains their roles in problem-solving; minor gaps in depth or integration.	Addresses several topics correctly but connections are basic or compartmentalized; limited depth in explaining interactions.	Mentions topics superficially with noticeable misunderstandings or fragmented links; little conceptual integration.	Shows minimal or incorrect understanding of structural analysis concepts; no integration.	ILO1, ILO2, ILO3, ILO4, ILO6, ILO7, ILO8, ILO9
Use of Free-Body Diagrams, Equilibrium, and	Provides precise FBDs and equilibrium reasoning to justify reactions and internal forces; articulates sign conventions and their	Uses correct FBDs and equilibrium with small lapses; reflects on sign conventions and	FBDs and equilibrium are generally correct but inconsistently justified; superficial	FBDs/equilibrium contain errors or are poorly justified; sign conventions	Misapplies or omits FBDs/equilibrium;	ILO2, ILO4

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Mapping to Course ILOs
Internal/External Forces	impact on shear/moment/deflection interpretations. Critically reflects on common pitfalls and error checks.	checks with reasonable clarity.	treatment of sign conventions and checks.	confused; limited error checking.	results unjustified or incorrect.	
Truss Analysis and Structural Idealization	Critically evaluates truss assumptions (pin joints, two-force members), member arrangements, and method choice (joints/sections/compound trusses). Provides reflective insight on limitations, load paths, determinacy, and practical detailing.	Correctly applies truss methods and discusses assumptions with some evaluation of limitations and load paths.	Applies standard methods with basic acknowledgment of assumptions; limited evaluation of arrangement/determinacy.	Mechanical application of methods with notable misunderstandings of assumptions or determinacy.	Incorrect or absent application; no understanding of assumptions or determinacy.	ILO1, ILO3
Beams and Frames: Shear/Moment, Qualitative Shapes, and Relationships	Accurately derives and interprets V/M diagrams, qualitative deflected shapes, and the differential relations between w–V–M; reflects on boundary	Mostly accurate V/M and shapes; discusses relations and checks with minor gaps.	Adequate diagrams with some errors; limited reflection on boundary conditions or checks.	Frequent errors in diagrams or qualitative shapes; weak linkage	Incorrect or missing diagrams; no understanding of relationships.	ILO2, ILO4, ILO6

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Mapping to Course ILOs
	conditions and physical plausibility checks.			between loads and responses.		
Deflection and Energy Methods (DE, Conjugate Beam, Virtual Work, Castigliano)	Selects and justifies the most suitable deflection method; compares alternatives; explains assumptions and error sources; reflects on unit/compatibility checks and physical interpretation of deflections.	Correct method choice and application; some comparison and reflection on assumptions and checks.	Applies a method with basic correctness; minimal justification or comparison; limited interpretation.	Method choice or execution flawed; weak understanding of assumptions/compatibility.	Misapplies methods or omits deflection reasoning entirely.	ILO4, ILO6
Indeterminacy, Force/Displacement Methods, and Moment Distribution	Insightfully discusses stability/determinacy, identifies redundants, and reflects on choosing force vs. displacement approaches and moment distribution. Addresses settlement, temperature,	Correctly identifies indeterminacy and applies chosen method with some discussion of effects and compatibility.	Basic identification and method application; limited treatment of secondary effects or compatibility.	Misidentifies indeterminacy or misapplies methods; overlooks compatibility and secondary effects.	No understanding of indeterminacy or methods; reflections absent or incorrect.	ILO1, ILO8, ILO9

Criteria	Excellent	Good	Satisfactory	Marginal	Fail	Mapping to Course ILOs
	and fabrication effects within compatibility.					
Influence Lines and Load Effects	Accurately explains and interprets influence lines for reactions, shear, and moment; reflects on moving loads and critical positions, linking to design decisions.	Mostly accurate influence line discussion; minor gaps in critical positioning or interpretation.	Basic understanding; limited depth on moving load strategies or design implications.	Misinterpretations of influence lines or moving load effects.	No understanding or incorrect statements.	ILO2, ILO4, ILO7
Assumptions, Idealizations, and Engineering Judgment	Explicitly states modeling assumptions (supports, continuity, member stiffness, linearity), evaluates their validity, and considers when superposition applies; discusses uncertainty and sensitivity.	States key assumptions and comments on validity and superposition with minor omissions.	Lists assumptions but gives limited evaluation or sensitivity discussion.	Unstated/unclear assumptions; superposition applied inappropriately; little judgment shown.	No recognition of assumptions; inappropriate or unsafe reasoning.	ILO1, ILO2, ILO3, ILO4, ILO6, ILO7, ILO8, ILO9

Communication and Feedback

Solutions for homework will be communicated via Canvas within two weeks of submission. Students who have further questions about the feedback including marks should consult the instructor within five working days after the feedback is received.

Course AI Policy

The use of Generative AI is permitted to assist students with brainstorming, drafting, and writing their homework.

Academic Integrity

Students are expected to adhere to the university's academic integrity policy. Students are expected to uphold HKUST's Academic Honor Code and to maintain the highest standards of academic integrity. The University has zero tolerance of academic misconduct. Please refer to Academic Integrity | HKUST - Academic Registry for the University's definition of plagiarism and ways to avoid cheating and plagiarism.